JOURNAL of the AMERICAN WELDING SOCIETY

Vol. 10
No. 10
OCTOBER
1931

WM. SPRARAGEN
Editor

AMERICAN WELDING SOCIETY

EDITORIAL AND BUSINESS OFFICES

33 West 39th St.
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JOURNAL OF THE AMERICAN WELDING SOCIETY

VOLUME X | OCTOBER, 1931 | NUMBER 10

1931 Fall Meeting

The 1931 Fall Meeting of the Society was held in Boston, Sept. 21 to 25. There was a registered attendance of over 350 members and guests. In spite of the current business conditions, the attendance at technical and other sessions compared favorably with those of other years. The caliber of papers and discussion were of a high standard of quality.

The meeting opened with the presentation of the report of the research investigations of the Structural Steel Welding Committee by its Executive Committee. This report is one of the outstanding reports of the American Bureau of Welding in recent years. It has received favorable editorial comment by the technical press of the country and by leading engineers. An editorial of the *Engineering News Record* in regard to the report is printed elsewhere in this issue.

On Tuesday morning an address of welcome was presented by the Honorable Mayor James M. Curley, with a response by C. A. McCune, chairman of the 1931 Fall Meeting and Exposition Committee.

Nineteen technical papers were presented on a wide variety of subjects. These papers are published in the September and October issues of the JOURNAL. The discussions will be printed in the December issue.

The entertainment features included a trip by boat on Tuesday afternoon to Salem Willows, including a shore dinner, and the annual banquet and dinner on Thursday evening. At this dinner an excellent address was presented by the Honorable Mayor James M. Curley.

The ladies' entertainment was one of the special features of the meeting and was enjoyed by all the ladies present.

Two motion pictures were presented, including Semi-Automatic Gas Welding and Underwater Cutting.

The meeting was held in connection with the annual Metal Congress and Exposition. Four other societies held meetings in Boston at the same time.

A Welding Magna Charta

Reprinted from Sept 17, 1931 issue of *Engineering News-Record.*

Publication of the report of the structural steel welding committee of the American Bureau of Welding is an event of much consequence. The investigation upon which the report is based provides structural welding with a firm foundation and in addition should go far to refute the charge that welding is a highly variable and uncertain method of joining structural steel parts, in nowise comparable to riveting. Both the plan and the results of the investigation are significant and important.

The idea for a broad program of research was conceived a number of years ago and urged as a necessary preliminary to the safe and proper development of the welding art. One of the results of the present report is to reveal the cohesive and comprehensive nature of that program and the thorough manner in which it has been carried out. In its conception and execution this investigation has seldom been equaled in the field of industrial research. Six years ago, when the first plans were being made, welding, while recognized as a process of potential value to the structural engineer, was barely more than an experimental element of structural practice. In an earlier age a new method such as this would have been left to work out its own salvation by trial and error. Riveting is an example of a process that developed almost wholly by such means. But the modern scientific mind is attuned to a faster pace. Accelerated experience was required, and the sponsors of the welding research set out to supply it. As a consequence, engineers have available today welding design data as extensive as would have been collected in a lifetime of trial-and-error use.

What has the investigation accomplished? In so far as stresses are concerned it supports those in accepted use as safe and reasonable, adding the important admonition that bending stresses should be provided for, or else avoided by eliminating eccentric conditions at the joints. No results were obtained that would justify different working stresses for welds of different sizes. Fillet welds placed transverse to the line of stress were shown to be 35 per cent stronger than those that were parallel. No harmful effects on the base metal from the welding heat were disclosed. All fusion welding processes displayed equally good results. Stringent qualifications for the welding operators were shown to be absolute necessities. Aside from these detailed technical results, the most important revelation is the indication that acceptable welds may be expected from any good fabricating shop; in the investigation work the welds made by 39 fabricators varied at most only 12 per cent from the average strength obtained by all fabricators.

This latter conclusion is perhaps the most important that came out of the research, for knowledge of the uniformity to be expected in commercial practice is wholly new and will have a profound effect upon the future growth and acceptance of welding by structural engineers. Once this acceptance has become general, the fabricating shops, which have often shown somewhat less than academic interest in the commercial development of structural welding, may be expected to lend a helping hand. It should not be a long step then to the institution of needed further research.

Welding is a method of such vast potentiality that it deserves the support of all branches of the civil engineering profession during its development stage. It is neither necessary nor proper to view it as a process that will entirely eliminate riveting, and thus scrap a huge investment in fabricating machinery. In the minds of many engineers, welding has been accepted as a companion piece to riveting. Its development should be fostered strongly and continuously with that end in view. The report of the structural steel welding committee provides a basis and an impetus for this development in both its commercial and research phases.

Authors of Fall Meeting Papers

(Not published in September issue)

EVERETT CHAPMAN, author of the paper on "Maximum Stress—Its Influence on Cost and Service Life of a Structure," graduated from the University of Michigan in Electrical Engineering, subsequently taking a Master's Degree in Physics. After teaching school for one year at Purdue University he went with the Lincoln Electric Company. He has been associated with Lukenweld, Inc., for the last year and a half as director of Engineering and Research.

GILBERT D. FISH, author of the paper on "The Yale University Group of Welded Buildings," received his Degree of Civil Engineer from Columbia University. He has, also, taught civil engineering and allied subjects in this institution and at summer sessions at Yale and Stevens Institute. Served as Captain and Major in the Corps of Engineers in this country and Europe during the war and since 1921 as consulting structural engineer in New York City. He designed the first large all-welded building for the Westinghouse Electric & Manufacturing Company in 1926-27. He designed the first welded railroad bridge for this company in 1927, and for the past five years has specialized in the application of arc welding to steel construction.

H. V. INSKEEP, author of the paper on "Welding of Copper and Brass Piping," graduated from the Massachusetts Institute of Technology in 1927 with a B. S. degree in mechanical engineering. The following year was spent in instructing in the Steam and Hydraulic Laboratory at the Massachusetts Institute of Technol-

egy. In July of 1928 he became affiliated with The Linde Air Products Company. After a period of training in numerous departments of the company, he was assigned to the Engineering Department, Development Section, and is at the present time connected with the Sales Department in the New York District as development engineer.

JOHN KJEKSTAD, author of the paper on "The Future of Welded Ship Construction," graduated from the Electrical and Mechanical School in Norway, 1903. He was engaged in engineering work in Norway in 1907 when he started studying electric welding in Sweden and Norway. He bought electric welding equipment and trained two operators, who left with him for the United States in 1909, where he started a marine welding business. He was engaged in welding work, repair and new construction up to 1929, when the Truss Weld Barge Company was incorporated for the purpose of building welded barges on his patented Truss Weld System. In January, 1931, the United Dry Docks, Inc., secured exclusive license to his two systems of welded ship construction for the Atlantic Seaboard, at which time he also entered their organization.

M. POWELL, joint author of the paper on "Large Welded Everdur Pressure Vessels."

His connection with welding began in 1920, at the plant of the General Electric Company in Schenectady. Prior to this he attended Union College in Schenectady. During the World War he served in the U. S. Navy, being discharged as Chief Machinist's Mate.

In 1925 he joined the forces of the Whitlock Coil Pipe Company in Hartford, Conn., as arc welding foreman. In 1928 he was made General Foreman of the Plant, which position he now holds.

HERBERT F. REINHARD, author of the paper on "Welding of Galvanized Steel," attended grade and high schools at Portland, Ind.; attended Purdue University four years and graduated therefrom with Bachelor of Science Degree in Chemical Engineering; 27 months in Service, both here and with the A. E. F. as Commissioned Officer of Coast Artillery; two years with Indiana State Board of Health as Chemist for Department of Foods and Drugs; three years in Engineering Department of the Prest-O-Lite Company, Inc., Indianapolis, Ind.; since January, 1925, Chief Engineer J. B. Colt Company, manufacturers of acetylene generators.

WILMER E. STINE, author of the paper on "Factors Affecting the Weldability of Steel," studied electrical engineering at Ohio University. Entered the service of the Westinghouse Electric & Manufacturing Company and was employed in various testing departments until the beginning of the war in 1917. During this period he pursued further studies in engineering at Carnegie Institute of Technology.

During the war he was in the Civil Service of the United States Navy Department inspecting power and propulsion equipment at Brooklyn.

In December, 1929, left the Navy Department to go with The Lincoln Electric Company as Research Engineer in electric arc welding.

C. J. THALE, author of the paper on "Welding of Piping in New York Hospital—Cornell Medical Clinic," was born and raised in Indiana. Graduated as Mechanical Engineer, Purdue University, 1908. Has been with Almirall & Company since 1910. Manager of Chicago office 1910-1926. In New York office since 1927. Member of firm and Sales Engineer. Paper covered Pipe Welding at the New York Hospital and Cornell Medical College Association group in New York City from the contractor's standpoint.

R. A. WEINMAN, author of the paper on "Fatigue Properties of Welds," graduated from Pratt Institute in 1908 in Electrical Engineering course. He spent two years in the General Electric Testing Department and has since been associated with the Research Laboratory, General Electric Company, Schenectady, N. Y.

Erratum

Attention is called to an omission of a footnote in connection with the article by Mr. Vincent P. Marran on "Large Diameter Pipe Arc Welded for Water Distribution," appearing in the August issue of the JOURNAL. The cuts used in connection with this article were furnished through the courtesy of the General Electric Company.

SECTION ACTIVITIES

DETROIT

The following is a tentative program of the meetings which the Detroit Section is planning to arrange during the winter.

Seven meetings are planned—with the possibility of a final meeting in the spring.

A joint meeting with the Detroit Engineering Society. Mr. Ellis of Pittsburgh Testing Lab., speaker.

Program on Resistance Welding by Mr. F. B. McBurney of the Federal Welding and Machine Company.

A joint meeting with the Detroit Safety Council with a speaker from the General Electric X-Ray Corp., on x-ray inspection of welds.

Industrial Pipe welding with a speaker from Linde Air Products Co.

A paper on arc welding or some form of gas welding by J. B. Manor of Weldit Acetylene Co.

High Speed Arc Welding by a speaker from A. O. Smith Corp.

A paper on Arc Welding of stainless steel.

PHILADELPHIA

The next meeting of this Section will be held on Monday, Oct. 19, in the Auditorium, Engineers Club. H. M. Priest, assistant engineer, American Bridge Company, will talk on "The Welding of One-Story Structures." It is also planned to show a motion picture of structural welding taken in Europe. This will be the first time that this picture will be shown in this country.

The September meeting was held on the 21st. The following papers were presented: "Protection from Fumes, Dust and Injurious Rays in Welding Operations" by F. H. Klein, engineering sales, Willson Products, Inc., and "Properly Protecting the Welder" by J. H. Reid, vice-president and sales manager, Chicago Eye Shield Company.

NEW YORK

The first meeting of the 1931-32 season will be held on Oct. 20 in the Engineering Societies Building. This meeting will be devoted to structural welding and the following subjects will be presented: Reinforcing Crane Runways with Arc Welding; Widening and Strengthening of Highway Bridges; Flame Cutting of Low Carbon Steel. The speakers for the evening will be: A. Vogel, General Electric Company; H. B. Mish, consulting engineer, and J. R. Dawson, Union Carbide & Carbon Research Laboratories.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-144. Electric welder with twelve years' experience desires position.

A-145. Electric welder on boiler and tank work desires position.

POSITION VACANT

UNITED STATES CIVIL SERVICE EXAMINATIONS

The United States Civil Service Commission announces the following-named open competitive examinations:

ASSOCIATE METALLURGIST
ASSISTANT METALLURGIST

Applications for the positions of associate and assistant metallurgists (optional subjects—ferrous metallurgy, nonferrous metallurgy, physical metallurgy, and ore dressing) must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than December 30, 1931, except that the Commission reserves the right to issue subsequent notice closing the receipt of applications before that date.

The examinations are to fill vacancies in the departmental and field services.

The entrance salaries for associate metallurgist range from $3,200 to $3,800 a year, and for assistant metallurgist from $2,600 to $3,200 a year.

Competitors will not be required to report for examination at any place, but will be rated on their education, training, experience, and fitness, and on a thesis, reports, or published writings.

Applicants must have been graduated with a bachelor's degree from an institution of recognized standing, with major work in chemistry, physics, or metallurgy. Certain specified experience or postgraduate education is also required.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or customhouse in any city or from the United States Civil Service Commission, Washington, D. C.

An Improved Product by the Use of Bronze Welding

By H. F. REINHARD

✦This paper was presented at the Fall Meeting of the A. W. S. in Boston, September, 1931, by H. F. Reinhard of the J. B. Colt Co.

DURING the past several years a great many sheet metal fabricators have had considerable experience with the bronze welding of galvanized sheets. The results of our own experience have been so favorable that it is thought a brief account of the application and results will be of interest to you.

I propose to tell you about the use of bronze welding as applied to light gage galvanized sheet steel and iron in the fabrication of a house lighting and cooking type Acetylene generator, and how the strength, life, gas and water tightness and resistance to shipping and handling damage were greatly increased by the use of bronze welding.

First, it might be well to explain the construction and operation of the generator I will refer to. Figure 1 shows the construction of the generator. It is 7 ft. 8¼ in. high and 3 ft. in diameter, outside dimensions. When installed, it is buried out of doors in the ground up to within 6 inches of the top of the generator. This prevents freezing of the water in the generating and bell seal chambers, facilitates charging and of course necessitates very little space for its installation.

The outside shell of the generator is a large cylindrical shaped galvanized tank. The bottom part of this tank is used as a large water reservoir into which the carbide drops. The upper part of the tank encloses a floating gas bell, a large carbide hopper holding 200 lb. of carbide at one filling equipped with a simple feed valve, and a gas filter. The motive power is gravity and the operation is entirely automatic. You will note that the hopper is supported on an inner cylinder known as the neck and that the neck is connected to the outer shell by a diaphragm or breast, thus forming the water seal in which the gas bell floats.

The gas bell is a very vital part. As gas is used, the bell lowers, pushing the carbide feed valve open allowing the carbide to drop into the water, making more gas. The gas raises the bell permitting the carbide feed valve to close automatically. The gas as used, passes through the filter into the service line.

The old and new method of making the gas bell seams is shown in Figure 2. The vertical seam was of single lock seam construction with solder sweated into the seam. It is now a simple butt weld. The bell top to bell body seam was of double lock seam construction with solder sweated into the seam. It is now a lap weld formed by turning a half inch flange on the top, sliding the top down over the cylindrical body and bronze welding the edge of the top flange to the bell body. With the lock seam and solder construction the thickness of the sheet metal used was limited to 20 gage because of the difficulty in double lock seaming in heavier gage metal.

In addition the lock seam and solder construction was open to the criticism that the seams would develop leaks if subjected to rough handling during shipment or in service. Adoption of bronze welding permitted use of 18 gage metal, and in addition helped to solve certain problems which are discussed later.

Figure 3 shows the unloaded position of a rather unique fixture designed to facilitate welding of the gas bell vertical or longitudinal seam. The fixture consists mainly of a pair of weighted arms which when clamped into position, hold each end of the rolled bell body separately and in such a way as to prevent all buckling and creeping. Copper inserts built into the

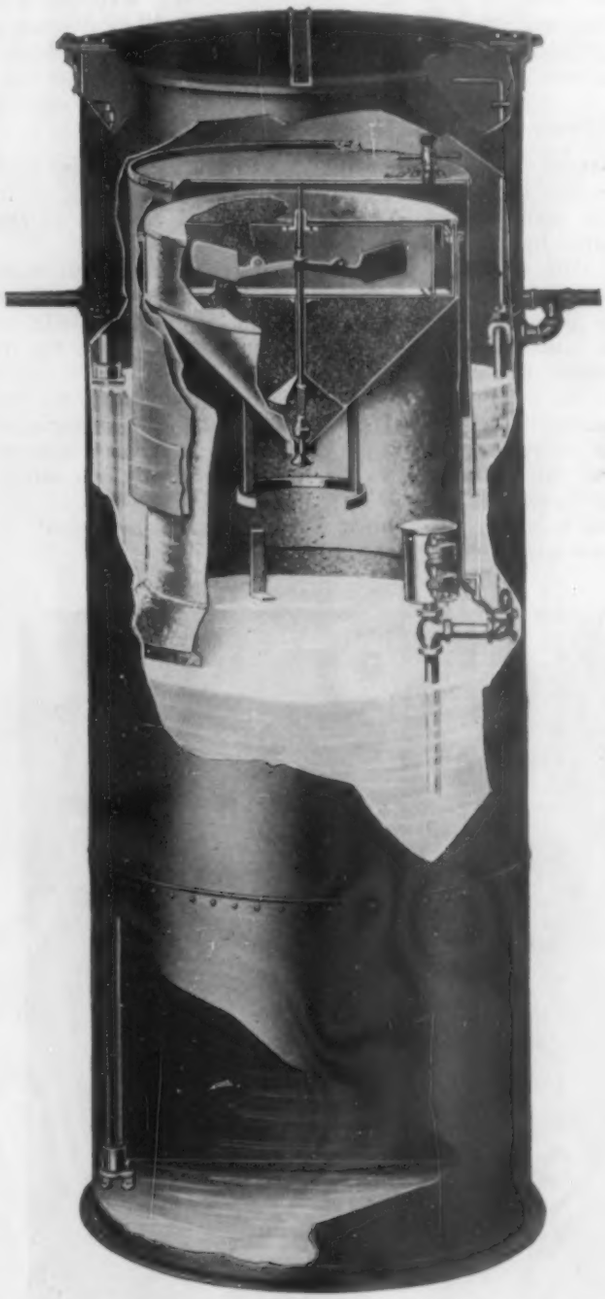


Fig. 1—Country Home Lighting and Cooking Type Acetylene Generator

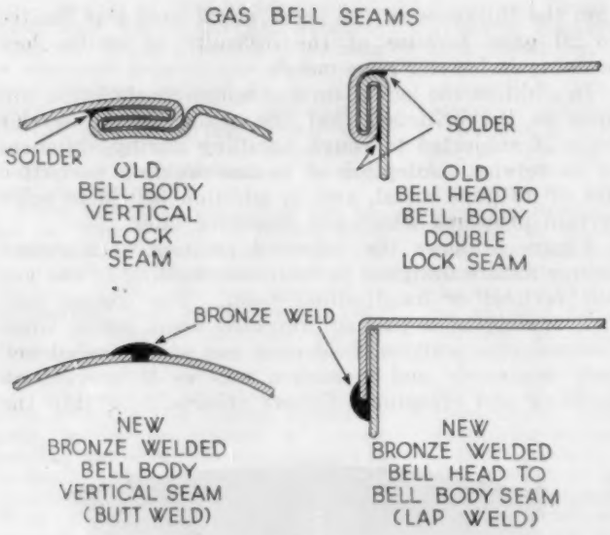


Fig. 2

fixture stakes conduct the heat away rapidly and thus reduce the amount of action on the galvanizing along the seam. Figure 4 shows the closed position of the same jig with the welder at work.

Difficulty was at first experienced with bulging of the gas bell head or top, due to the application of heat on the outer circumference of the head. This bulging is controlled by a suitable jig which holds the top in proper alignment, the bulge being taken into account in the dimensions of the gas bell. Figure 5 shows the unloaded position of the fixture used. It is a horizontal rotating type fixture clamped by means of a lever and catch arrangement which forces a spider against the open end of the bell and presses the top of the bell to the body against a plate with lugs spaced at intervals.

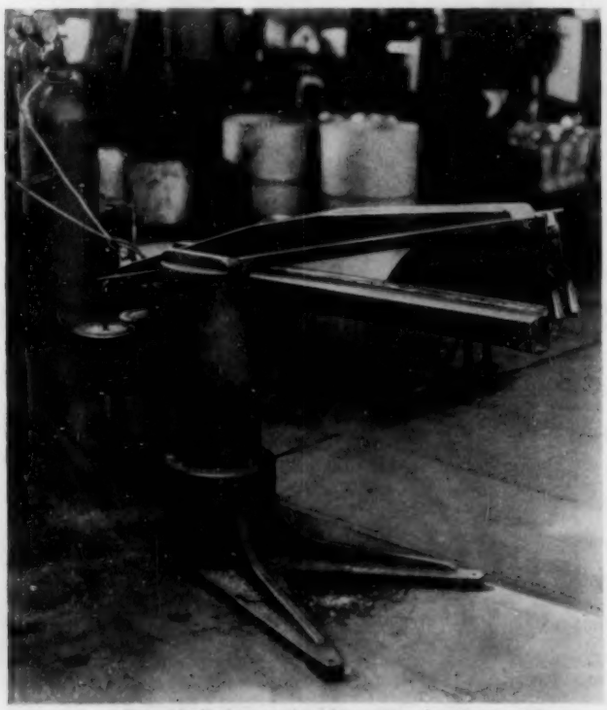


Fig. 3—Jig for Longitudinal Seam (Unloaded Position)

Figure 6 shows the same fixture loaded and with the welder at work.

I might at this point say a little more about the bulge in the gas bell top, as the heavier metal used together with the bronze welding process solved a rather vexing problem.

Figure 7 will help to explain the matter. The distance from the center of the gas bell top to the bottom of the gas bell is very important as a reinforcing plate in the center of the gas bell top actuates the hopper feed rod as the bell lowers and rises, and it is important that the amount that the feed rod is depressed just

Fig. 4—Longitudinal Seam Being Bronze-Welded

before the gas bell lands, be accurately controlled.

With No. 20 gage metal and the old lock seam construction, the gas bell top would usually be in a convex position when the bell was lowered into the generator, and it would usually snap down to the concave position when the gas bell was being lifted out of the generator. The trouble was that one could not be sure that it would be in the positions just mentioned and if it were not in the convex position when the bell landed, the hopper feed rod would not be depressed the proper amount. In addition this flexing back and forth tended to break the solder in the bell top to body seam. With the heavier metal which we were able to use in the gas bell combined with the bronze welding process, we soon found that we were able to definitely control the bulge in the gas bell top and to permanently fix it in the convex posi-

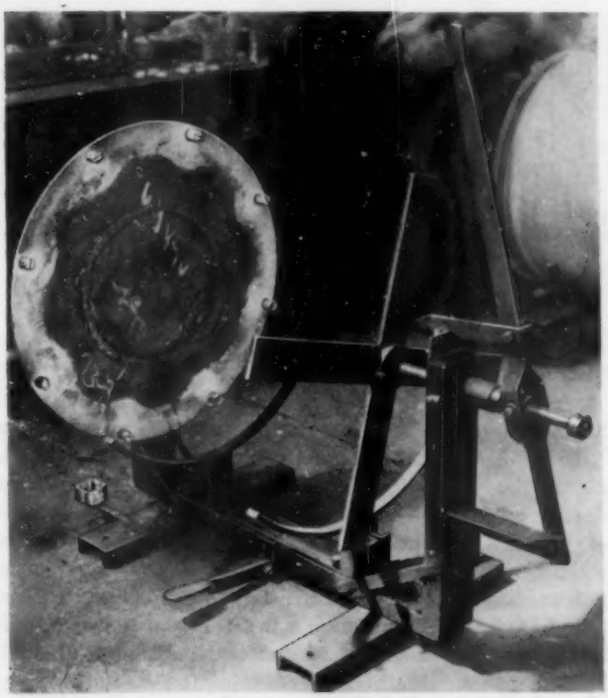


Fig. 5—Jig for Head Seam

tion. The result is that we are now able to very accurately control the distance between the reinforcing plate in the center of the gas bell top and the bottom of the gas bell. This insures proper operation of the hopper feed valve at all times.

Mention has already been made of the fact that bronze welding permitted using heavier gage metal in the gas bell. As the weight and top area of the gas bell govern the pressure, the extra weight of the sheet metal used when bronze welding is compensated for by using a narrower and lighter weight band on bottom of gas bell. The cost of material is therefore not appreciably affected.

The old method of joining the neck to breast or diaphragm as shown on the left half of Figure 8, consisted in turning a half inch 60 deg. flange on the bottom of the neck and then joining the neck and breast by riveting and soldering. You have already noted that the neck is required to support the hopper as well as the 200 lb. of carbide which the hopper holds, and it sometimes happened that if the hopper was lowered into the neck too roughly, a leak would develop at the riveted and soldered neck to breast joint. The right half of Figure 8, shows how bronze welding eliminated the riveting and soldering without changing the construction in any other way. At the same time bronze welding of the short transverse seam was adopted in place of the riveted and soldered construction previously used.

Bronze welding is used to eliminate a heavy and costly threaded flange fitting which was riveted and soldered to the generator neck and through which the pipe leading from filter to service line passed. The left half of the illustration shows the old method of riveting and soldering the heavy flange fitting to the neck, short pipe fittings being screwed into the fitting from either side. The right side of the illustration shows how the costly threaded flange fitting was eliminated by the simple expedient of bronze welding, a regular pipe elbow through the breast or diaphragm. This change materially increased the strength of the connection, decreased the possibility of leaks, and eliminated the costly threaded flange fitting. In addition it has permitted doing way with the bottom four inches of the gas bell seal chamber, since under the old method, landing brackets for the gas bell had to be provided above the flanged fitting in the neck. The saving in metal is considerable. We now have the same height of bell seal with only 36 gallons of water in the bell seal chamber as compared to the 44 gallons previously required. This also provides an appreciable economy in those very cold climates where an anti-freeze solution must be used in the gas bell seal chamber.

The left half of Figure 9 shows the old riveted and soldered bottom to lower section seam. These seams were carefully tested for leaks at the factory but occasionally rough handling in transit or in installing, resulted in slight leaks. Such leaks were especially difficult to repair if not found until after installation of the generator, as it was usually necessary to dig the generator out of the ground. Bronze welding was adopted and the right half of Figure 9, shows the seams as bronze welded.

A rather small but important change made possible by bronze welding is in the casting used to support the agitator pipe. This casting was formerly riveted to the bottom and the rivets soldered on the underneath side to prevent water leakage. Occasionally through rough handling in transit or usage, the solder would break loose around the rivets and a leak would result. Doing away with the rivets by bronze welding the casting to the generator bottom, eliminated any chance of leaks at this point.

There are other points in this particular generator where bronze welding is effectively used, such as in bronze welding the seal tube where it passes through the breast or diaphragm, bronze welding the gas bell air inlet plug flange and the gas bell handle ears, but to describe the applications would be more or less a repetition of what I have already said.

It might be well to say just a few words about welding rods. Although we were getting very good results

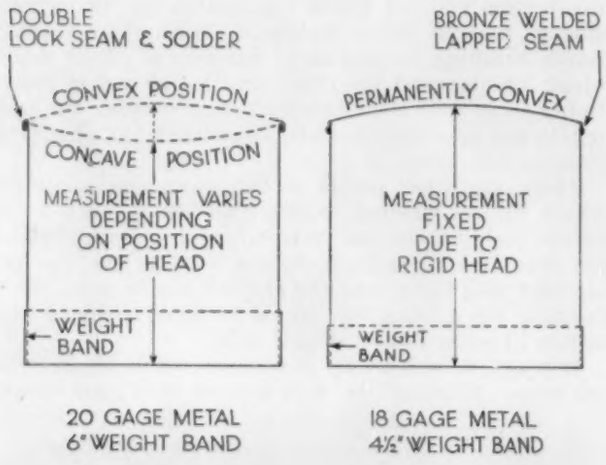
Fig. 6—Head Seam Being Bronze-Welded

with a regular bronze welding rod, in the early part of 1929 a new High Strength Bronze Welding Rod was put on the market which is unique in possessing certain strengthening and fluxing agents.

The results secured in using the new High Strength Bronze Welding Rod were much better and might well be summed up as follows: The weld metal during deposition flows and tins very smoothly and easily; while welding there is a notable freedom from boiling and fuming of the weld metal; elimination of oxide and gas inclusions makes the weld metal remarkably free from blowholes and sound in every respect; tensile strength of welds average considerably higher than those obtained from other bronze welding rods; remelting of the weld has little or no effect upon the structure of the joint.

The results we have secured with bronze welding have been all and more than we originally expected. Previous to the adoption of bronze welding a careful inspection of gas bells that were returned to the factory for various commercial reasons, showed that 24 per cent had developed slight seam leaks due to the

Fig. 7

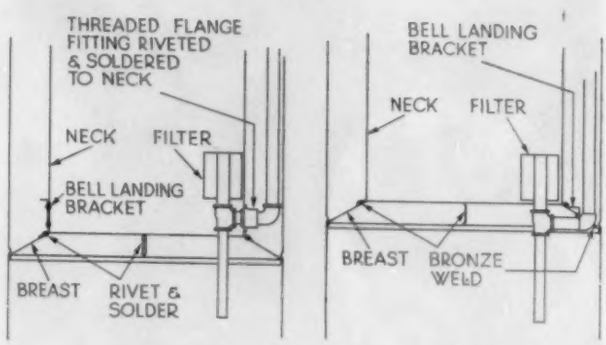


rough handling in transit. No leaks have been found in any returned bronze welded gas bells. This record is the best kind of proof of the merits of the welded seam. Tests made on a Riehle physical testing machine showed that bronze welded seams were 315 per cent stronger than the soldered double-lock seams.

As to the cost of bronze welding compared to lock seaming and soldering, riveting and soldering, etc., it is difficult to give a definite general answer. Where the bronze welded joint simply replaces one made by the other methods mentioned, the first cost may be slightly higher. Where bronze welding permits doing away with expensive threaded flanges in similar construction or in saving of material, the slightly added initial cost of bronze welding is more than compensated for. The freedom from future trouble and expense guaranteed by bronze welding is a rather intangible factor but an important one. In a farm lighting and cooking generator it is of paramount importance. In a device similar to the generator in question, bronze welding should result in a considerable saving over other methods of fabrication.

A question which naturally occurs is what effect bronze welding has on the galvanizing adjacent to and back of the weld and the consequent effect of any action

Fig. 8

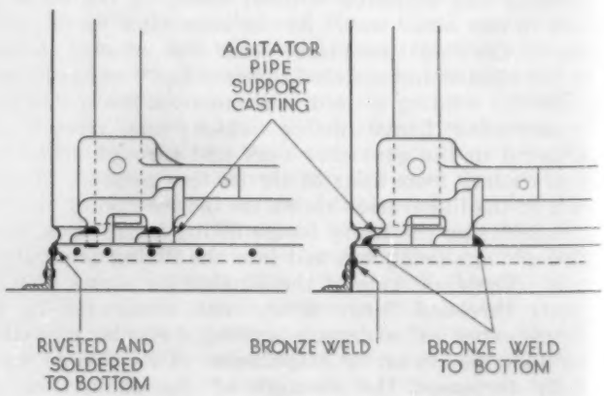


as well as of the welding rod on rusting and corrosion.

In bronze welding galvanized metal, the galvanizing along the edge and back of the weld is somewhat destroyed but the damage is much less than might be expected. Less heat is of course required for bronze welding than for steel welding and any damage to the galvanizing is likewise less. It should also be remembered that the galvanizing along the seam is also damaged by other methods of fabrication such as double lock seaming. Methods of fabrication usually expose an unprotected sheared edge but in bronze welding the edge is re-protected by the weld itself.

Where the galvanizing is damaged during welding or lock seaming, rusting or corrosion can be prevented by re-tinning or by an application of other suitable protective coatings. In the generator I have been describing, all bronze welded seams except the gas bell seams are coated with a black asphalt paint. A paint which dries very quickly, and which I believe consists of vulcanized gum rubber dissolved in benzol is brushed around the welded seams of the gas bell, inside, and the bell is then submerged bottom downward in the same rubber paint so as to thoroughly coat all outside seams. The outside of the gas bell vertical seam is re-tinned first as it is subject to particularly corrosive influences floating as it does in a water seal and with the oxygen of the air present in abundance. Without going into the electrolytic and other theories of corrosion, the answer to the rust and corrosion question is that in the several years since we have adopted bronze welding, we have had no trouble from rust or corrosion, the simple protective coatings being sufficient, if indeed, in most instances, they are needed at all.

Fig. 9



The Yale University Group of Welded Buildings

By GILBERT D. FISH

✦ Paper presented at Fall Meeting, A. W. S., Boston, September, 1931, by Gilbert D. Fish, Consulting Engineer, Consulting Structural Engineer to Westinghouse Elec. & Mfg. Company.

COMPLETELY arc-welded steel frames are being used for a group of four unrelated buildings at Yale University. All four are in charge of different architects and no two are similar in form or architectural style. Three general contractors and two steel contractors are employed on the group. At the time of writing, late in August, 1931, two are under erection and steel for the other two is being fabricated.

The first to be started is the smallest, known as the Briton-Hadden Memorial, which will house the Yale *News*. It is a four-story brick-bearing-wall structure, the style and size suggesting a private residence. Only a few tons of steel are required, and the operation is not very interesting structurally, except perhaps in respect to the light gable roof framing.

The Sheffield Scientific School Administration Building, now nearly completed as to steel, is five stories high but has an eleven story tower in the middle. It is of Gothic architecture and is to be faced with stone. The steel skeleton framework weighs 800 tons and is very irregular. Most of the beam-to-column connections are eccentric. The roof is steeply pitched and has many gables. The tower columns are offset and are carried by girders requiring uncommonly heavy connections. Three crawler cranes have been used, one to unload and distribute steel and two for erection. After erection and welding of the first tier of steel the erecting cranes were placed upon the first floor framing and used to erect steel from first tier to main roof.

The Dormitory Quadrangle at College and Elm Streets is laid out as a hollow square. It varies from four stories to seven, has a complicated gabled roof with occasional towers and turrets, and is extremely irregular in floor plans. The framing is so lacking in repetition that all the columns and most of the beams and roof members require individual shop drawings; a large proportion of the columns are offset at various tiers, and a number of heavy members are therefore needed. Generally, the framework is no heavier than for apartment house construction, but it is far more complicated. The weight of steel is 940 tons.

In striking contrast with the Sheffield Building and the Dormitory Quadrangle is the addition to the Yale Medical Center and New Haven Hospital, known as the Sarah Wey Tompkins Memorial. In harmony with the building group to which it belongs, it is a simple rectangular wing, six stories high, with brick skeleton walls and flat roof; 560 tons of steel are required for the ward unit and alterations to an existing building included in the present operation.

The Yale group has offered an opportunity to study welded construction in application to a variety of institutional buildings, which are very different from the factories, mill buildings, shops and relatively simple commercial structures which have heretofore comprised most of the welded and partly welded buildings. Not only is the variety of welded connections necessarily far greater than in any earlier welded construction, but the position of the university as an owner without commercial interest in any construction method has provided an exceptional opportunity to test the feasibility and economy of welding under open market conditions with a variety of architects and contractors. It should be understood that these buildings are welded throughout, not merely as to field connections.

Fig. 1—Yale Sheffield Administration Building. Heavy Framing Under Tower

It is well known in contracting circles that bids on individual buildings are far from conclusive as to the relative economy of competitive construction methods, especially at a time when bidding is unusually erratic as at present. It is therefore not to be regarded as proving any general relationship, but it is interesting nevertheless that on the Sheffield Building the two lowest bids on the welded basis were lower than any of the numerous bids based on riveting, the saving in the awarded price being about 13 per cent, and that on the Dormitory and the Hospital the two steel contractors are handling the work at prices for which they would not furnish riveted construction. The Sheffield Building was the only one for which bids based on riveting were received but on the Dormitory job shop-riveted-field-welded proposals were received which did not compare favorably with all-welded construction.

There are strong reasons for beileving that it is necessary to use welding for shop work in order to accomplish any substantial economies. Substituting welding for riveting in erection only, while effective in reducing noise, cannot save any considerable expense, unless perhaps by a system of erecting plain mill material and welding it in place. The writer believes that the practice of field-welding buildings which are shop-riveted, while entirely sound as to engineering and sensible from the viewpoint of the owner who wishes to avoid riveting noise at the building site, is a temporary response to the demand for quiet construction and will give way to the more economical all-welding method.

It is interesting, but not surprising, that both of the fabricators handling the Yale contracts prefer to do as much of the work as possible in the shop rather than to exercise the option of sending a large proportion of

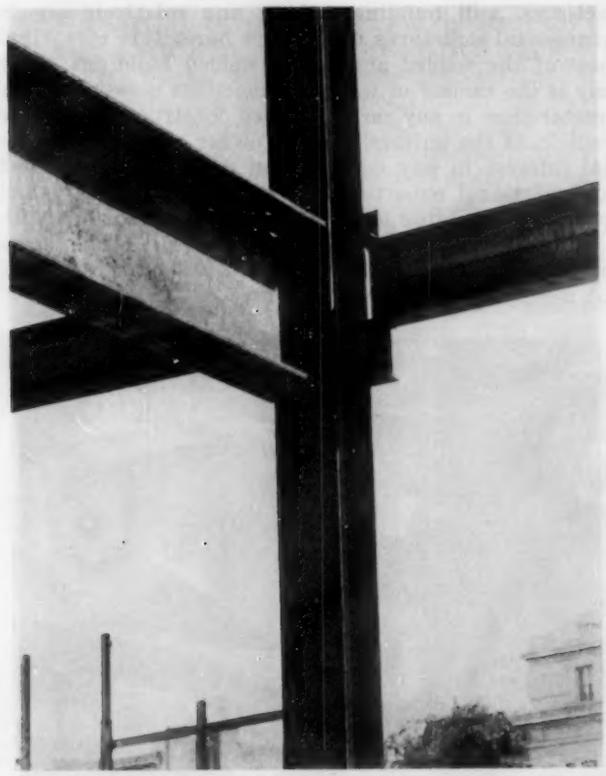


Fig. 2—Yale Sheffield Administration Building. Typical Framing at Outer Wall

beams directly from rolling mill to building site. In partial explanation of this, it may be remarked (1) that the mill-in-transit return on freight prevents any loss to the contractors from taking the steel to their shops instead of sending it directly to New Haven, (2) that in these buildings most of the beams are flush-top and therefore nearly all pieces require some preparatory work before erection, (3) that there is not much room alongside the buildings for ground preparation, and (4) that unit costs are much higher in the field than in the shop.

These buildings do not offer particularly good opportunities to save steel by redesigning to suit welding; they lack trusses, plate girders, cantilever balconies and lines of beams which might be made continuous. Some redesigning of roof frames, cover-plated girders and cantilevers has, however, accomplished appreciable savings. The connections designed for welding weigh, on the average, under 2½ per cent of the total steel, as compared with a probable 5 per cent if riveted.

The connections were designed for economy with respect to weight, amount of welding, and simplification of fabrication, and for reasonable convenience in erection. Generally, one or two erection bolts occur at column connections, but not at flush beam-to-beam connections. In the Sheffield and Dormitory jobs, where the beams are relatively numerous and most of the columns are not more than moderately heavy, the erection holes are concentrated mainly in the columns and very few beams have to be punched; in the Hospital job the columns are heavier and the beams less numerous, and the holes are therefore confined to the beams, no hole occurring in any column. In the Hospital most of the beams are connected to columns, and these connections are of the seat-and-top-angle type without web connections. In the Sheffield and Dormitory buildings, where the framing includes almost every known eccentric, skew and sloping relationship of beams to columns and all possible elevation differences in beam-to-beam connections, the joint designs are extremely variegated and naturally have no uniformity of style. These joints range in working capacity from 6000 to about 250,000 lb. Over 10,000 beams are used in these buildings, and as there are not many duplications, there are necessarily thousands of different joint details.

In all these structures, most of the beam-to-column connections include beam seats which are shop-welded to the columns; in some cases these are little more than erection seats, most of the load being carried by web connections, but more frequently the seats carry the entire load or a substantial part of it. Beams supported by other beams are generally attached to them by web connections, erection bolts not being used. All column splices are of the butt plate type, which is simple and cheap and which provides as much bending resistance as may be desired.

In many cases beams are supported wholly or in part by welding their webs directly to column flanges or the webs of supporting beams. Where the supporting member is rigid, secondary bending stress occurs in this kind of joint due to beam deflection, and in any such case care has been taken to proportion the welds to the supported beam web in such manner as to insure that any yielding shall occur in the beam web rather than in the welds.

Flush-top beam-to-beam connections are erected with the aid of shop-welded plates projecting beyond the coped ends of the supported beams; these plates rest on top flanges of supporting beams and hold the carried members at the desired elevations until the web connections are welded. These projecting plates are very convenient and inexpensive and make erection easy.

In preparing to take bids on the steel for these buildings, all typical connections and many special ones were designed and drawn as part of the information furnished to bidders; in addition, weights of connection material and quantities of shop and field welding were accurately estimated and reported to bidders. This preparatory work was largely responsible for the close estimating done by the lowest bidders. It is believed that owners contemplating welded construction would be well advised to have their work laid out in advance in order to obtain favorable bids; the results of asking for bids on

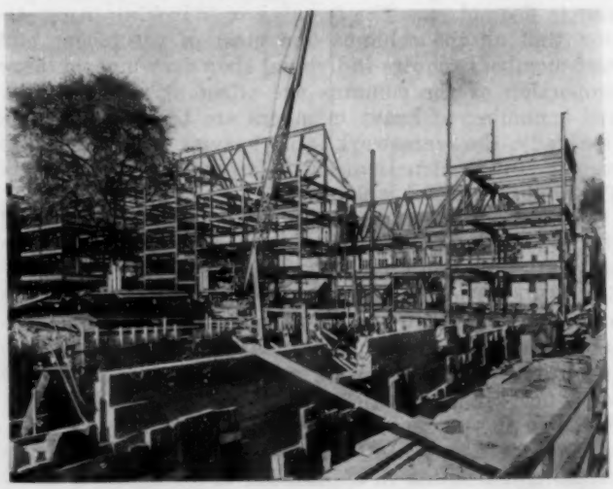


Fig. 3—Yale Dormitory Quadrangle About One-Third Erected

welded construction without furnishing definite information to contractors is usually to receive higher figures than are quoted for riveted construction.

Some photographic illustrations accompanying this paper show representative joints in the Sheffield Building, but field work on the dormitory and hospital jobs is not advanced enough for photography. The writer believes that many of the joint types used in these buildings will again be used on future work, but does not offer them as joint design standards because it is probable that the evolution of design for welded buildings will bring rapid and perhaps striking changes in a year or less. Some of the joint types were used in 1926 and were found satisfactory enough to retain on succeeding work. A few of the designs appear to be hardly worth preserving.

The system used for guiding the detailers in making the shop drawings and for showing the field welders what welding is required, is to prepare drawings of all joint designs to be used, assign serial numbers to these designs and mark these numbers on the framing plans at the intersections of the members. Experience with the very numerous serial numbers required for the first two of the Yale buildings led to a more comprehensive system on the Dormitory job, for which combinations of numbers and letters are used; each number represents a type for which a single design sketch suffices, and the several letters used for different cases of that type stand for various sizes and therefore various strength values. The only apparent drawback of this system is that any departure from these joint designs which may be found necessary when the shop drawings are made, necessitates a revision of one or more joint numbers on the erection plans and possibly requires some supplementary joint designs to be issued.

Fig. 4—Yale Sheffield Administration Building. A Corner of the Tower

The work of detailing welded buildings appears to be no more exacting or difficult than the corresponding work on riveted construction, but it is certainly not much if any easier. The saving of dimensioning for rivet holes is offset by the need for specifying sizes and lengths of welds, and the greater variety of welded connections is an added burden. The writer has handled the shop drawings on two of the Yale buildings in order to study the detailing problems of welded construction at first hand, and is impressed by the need for comprehensive classification of joint designs for ready reference and for reduction of drafting room labor.

Shop and field inspection of the steel for these buildings is handled by the writer's organization in much the same way as the corresponding work in riveted construction is handled by firms engaged in inspection as a specialty. A resident inspector at each fabricating shop, trained primarily in structural welding but having experience in inspecting steel and reading shop drawings, examines and qualifies all welding operators, passes on welding equipment and electrodes, inspects all welds and breaks off occasional connection angles to study the weld fractures, checks all steel sections and joints against the shop drawings, paints his initial on every accepted piece before it is shipped, makes sure every welder initials his own work, and makes weekly reports of all objections and difficulties. A resident inspector at the building site examines the connections on all steel as delivered to discover any damage during transit, examines and qualifies all field welding operators, passes on equipment and electrodes, watches every operator at work several times daily, inspects every joint and every single field weld for agreement with drawings as well as for quality, examines the shop welds as a re-check on the shop inspector, measures the columns and beams as a second defense against errors in section, supervises cleaning and painting, marks his initial on every joint when he passes it, and checks off inspected joints on the erection plans to insure completeness of inspection. Mere general inspection of quality is by no means sufficient to insure safety in any form of construction. As the inspectors are men of highly specialized training and are responsible only for proper execution of work in accordance with the drawings, the writer visits each shop and each building site about once a week, not merely to act on questions which arise and make sure of the systematic conduct of the work, but especially to look over the connections for questionable or dangerous details which may have escaped attention on the drawings; quite a few things of this sort come to light, and the writer would not at present be content to supervise any such complicated welded structures as these without the supplementary check-up.

We do not often resort to laboratory testing of weld specimens because experience has shown that close observation of a welder's work, continued day after day with occasional breaking of welds which have not been made for exhibition, affords a degree of control to which laboratory tests add very little, provided, of course, that the inspector is highly experienced. In dealing with situations where considerable numbers of welders have to be recruited, the inspectors have to become instructors and work with patience to overcome bad welding habits and to train the new men to work to size; welders who do not at once show ability to hold a steady arc and obtain thorough fusion are summarily rejected.

Setting high standards for welding workmanship, constant checking up on the individual welders' fusion and other characteristics, passing all shop-inspected work under the review of a senior inspector in the field, and weekly visits by the engineer to shop and field, make a combination of safeguards which leaves very little to chance. If the precautions seem over-elaborate, let it be understood that the joints in

the buildings under discussion have been designed closely to the maximum stresses allowed by the A. W. S. Building Code and require the full strength which they are supposed to have. Expressing all sizes of welds in terms of their volume equivalents in ⅜-in. fillet welding, the average for these buildings is about 8 ft. of shop welding and 4 ft. of field welding per ton of steel. If double these quantities had been used, some relaxation in inspection routine might be permissible.

In order to reduce the welding materially below these figures on future work, and to reduce the weight of connections below the 2 to 2½ per cent now required, it will probably be necessary to introduce improved weld metal with increased ductility. Vastly improved joint designs, which will become possible when danger from secondary strains and temperature stresses in ordinary weld steel is no longer a vital consideration, may be expected to bring marked changes in welded building construction by 1932, and to widen the margin of cost saving which now exists in favor of the method.

Yale University building operations are under the direction of Mr. Thomas Farnam, Associate Treasurer; Mr. S. H. Francis is Superintendent of Construction. For the Sheffield Building, Messrs. Zantzinger, Borie & Medary of Philadelphia are architects, Messrs. Gravell & Duncan are structural engineers, Dwight Building Co. of New Haven is general contractor, and Pittsburgh Bridge & Iron Works steel contractor. For the hospital, Mr. Henry C. Pelton is architect, Messrs. Lange & Noska are structural engineers, Sperry & Treat Co. of New Haven is general contractor, and Palmer Steel Co. steel contractor. For the dormitory quadrangle, Mr. John Russell Pope is architect, Elwyn E. Seelye & Co. are structural engineers, Marc Eidlitz & Son are general contractors, and Pittsburgh Bridge & Iron Works steel contractor. For the Briton-Hadden Memorial, Messrs. Adams & Prentice are architects, Sperry & Treat Company general contractor, and the Palmer Steel Co. steel contractor. Churchward & Co. of New Haven are field welding contractors on the Palmer Steel Co. jobs. Mr. R. Kraus is chief steel inspector on the buildings.

Fatigue Properties of Welds

By R. A. WEINMAN

✦ Paper presented at Fall Meeting, A. W. S., Boston, September, 1931, by R. A. Weinman of the Research Laboratory, General Electric Co.

IN all processes of fusion welding, low carbon steels were the first to be used for welds. Soon after considerable success had been attained with these steels, other ferrous alloys were successfully used which gave higher mechanical strength and possessed other advantageous properties, both commercial and economic.

There is very little known about the effect of such metals as chromium, nickel, silicon, manganese and other non-ferrous constituents of steels as used in electrodes for welding. It would seem, from our knowledge of these metals by themselves, that they should impart to the weld some characteristics other than might be expected from low carbon steel.

The purpose of this investigation is to show the effect of the addition of these metals in steel as filler rod and base metal.

INTRODUCTION

This paper deals with mechanical properties of metals deposited by means of the atomic hydrogen flame in the form of welds and built-up specimens. The most important of the mechanical properties considered in this investigation are those involving fatigue under continued alternating stress.

The specimens used for the tests represent samples produced by at least fifteen different operators who have been associated with our company during the last two years or more, the majority being engaged in welding production work.

Testing Machines and Their Location

All static tests were conducted in the Testing Laboratory of our company with an Amsler hydraulic tension testing machine.

Fatigue tests on built-up specimens of metal were conducted at the Rensselaer Polytechnic Institute at Troy, N. Y., by Prof. T. R. Lawson and his associate Prof. E. R. Wiseman. The R. R. Moore fatigue machine was used for these tests since it requires the smaller specimen, as shown in Fig. 1.

This machine is a double, plain bearing, rotating beam type having a speed of 1725 r.p.m. Additional parts were attached to the machine to release the load and also prevent starting again should the motor power fail during the absence of an attendant. (See Fig. 2).

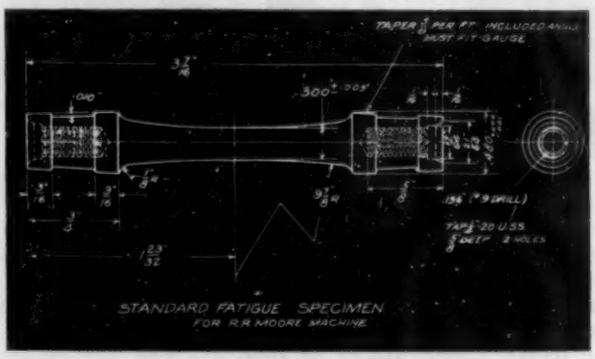


Fig. 1

Slight modifications were made in the specimen where it was held in the bearing of the machine, as shown in Fig. 1.

The welded fatigue specimens were tested in the Turbine Department of the General Electric Company at Schenectady in machines designed by C. E. Weaver.[1] These are modified forms of the White Souther and McAdam types, operating at a speed of 2200 r.p.m. Fig. 3.

The type of specimen used for tests in this machine, shown in Fig. 4, was a rotating cantilever beam, the reduced section of which was similar to the McAdam type C[2] specimen.

A single V weld was placed at the position of max-

[1] Manager's Office, General Electric Company, Schenectady, N. Y.
[2] Chem. & Met. Eng. 1921, 25, p. 1081.

Table 1—Analysis of Metal in Original Form

Filler Rod	C	Mn	Cr	V	Si	Ni	P	S
1	0.10	0.25 0.45					0.035	0.045
2	0.50	0.67	0.94	0.18			0.027	0.019
3	0.46	0.61				3.41	0.018	0.020
4	0.47	0.56			1.98		0.04	0.040
5	0.13–0.18	0.40 0.60			trace		0.035	0.045
6	0.08–0.16	0.60 0.90					0.09 0.13	0.075 0.150
7	0.13–0.18	0.40 0.60			trace		0.03	0.045

Plate Metal Used

	C	Mn	Cr	V	Si	Ni	P	S	Mo
S	0.09 0.18	0.50 0.40					0.018	0.043	
H	0.28 0.35	0.50 0.60	1.10			1.75 2.25	0.030	0.040	0.25 0.40
325	0.50	0.57	1.08	0.17	0.25				

imum stress, S in Fig. 4, which was in the plane whose diameter is 0.4687 in., although the stress from the bottom of the fillet over a distance 1½ in. from that position varied only 1½ per cent. The end of the specimen that fitted into the chuck was ground to conform to a standard No. 3 Morse taper.

This machine was also equipped with a load release and no-voltage release in case of accident to power supply to motor. The load in both fatigue machines was gradually applied, after the specimen was rotating at full speed, by a lever mechanism which was held in final position by a solenoid excited within all

Fig. 2 (R. R. Moore Fatigue Testing Machine)

circuit breaking devices to the power supply of the motor.

Material Used

The metals used for filler rod materials in these tests are listed in Table 1. Nos. 1, 5 and 7 represent low carbon filler rod which received a surface treatment for the purpose of arc welding. No. 6 is a bare wire which was used for machine parts only. Nos. 2, 3 and 4 metal contained small amounts of chromium, nickel and silicon respectively.

The base metal marked S is common machine steel with a tensile strength of 60,000 lb. per square inch and proportional limit of 50 per cent of this steel. H metal was selected for these tests because of its high tensile strength, approximately 150,000 lb. per square

TABLE 2—ALL DEPOSITED METAL

Specimen	Tensile Strength in Lbs. per Sq. In.	Yield Point in Lbs. per Sq. In.	Proportional Limit in Lbs. per Sq. In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent	Maximum Fiber Stress in Lbs. per Sq. In.	No. of Cycles	Remarks
1 Avg	50,800	33,700	31,700	28.2	65.4	39,000	3,284,000	To failure
						36,000	750,000	To failure
						32,000	4,257,000	To failure
						30,000	5,497,800	To failure
						28,000	22,036,100	No failure
2 Avg	111,450	76,700	69,000	7.3	30.3	42,000	1,135,700	To failure
						40,000	1,201,400	To failure
						35,000	2,043,000	To failure
						25,000	10,839,300	No failure
3 Avg	80,400	62,400	46,000	14.6	31.0	44,000	484,000	To failure
						40,000	1,615,200	To failure
						35,000	6,102,700	No failure
						30,000	15,460,000	No failure
4 Avg	67,000	42,000	35,000	15.5	33.0	42,500	759,300	To failure
						40,000	1,803,000	To failure
						37,500	2,031,600	To failure
						34,000	2,317,900	To failure
						28,800	51,403,500	No failure
5 Avg	53,350	35,100	34,500	36.0	81.3	32,000	2,582,000	To failure
						30,000	2,534,000	To failure
						28,000	3,342,000	To failure
						27,000	4,652,000	To failure
						22,000	51,618,100	No failure
6 Avg	58,500	33,600	32,000	20.1	48.0	35,500	887,700	To failure
						32,900	4,021,600	To failure
						30,000	50,325,400	No failure
7 Avg	52,440	32,200	30,700	26.5	49.4	30,000	826,400	To failure
						28,500	7,109,400	No failure
						28,000	50,402,300	No failure

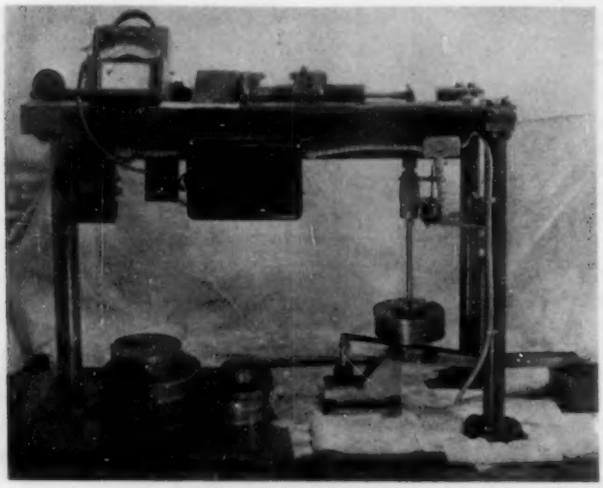


Fig. 3 (Rotating Cantilever Type of Fatigue Machine)

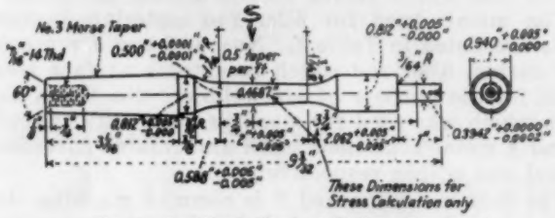


Fig. 4 (Cantilever Type of Fatigue Specimen)

inch, and a proportional limit 10 to 20 per cent of the tensile strength.

No. 325 base metal was selected for special tests which will be referred to later.

Data

In Table 2 the various tests are recorded for filler rod alone. This includes all metal listed in Table 1 from No. 1 to No. 7 inclusive. These specimens were built up, as shown in Fig. 5, by continually building up the metal on a ¾-in. diameter area to a length of 3½ in. for fatigue specimens and of 5¼ in. for tension specimens.

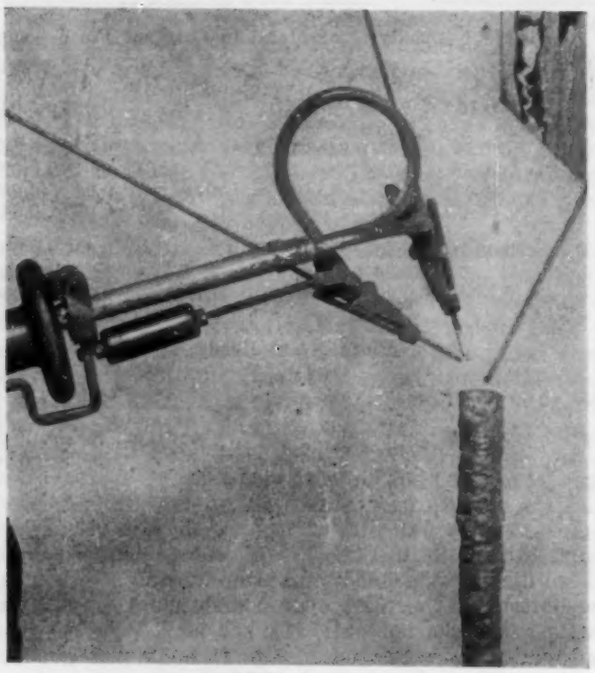


Fig. 5 (Built Up Test Specimen)

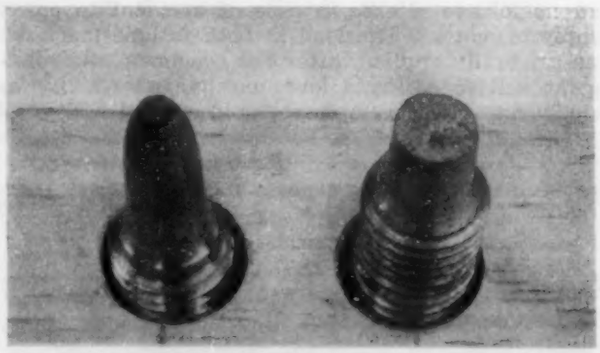


Fig. 6—Reduction of Area of Tension Specimens. All Deposited No. 5 and No. 2 Filler Rod

TABLE 3—SINGLE V WELDS ON S METAL

Specimen	Tensile Strength in Lbs. per Sq. In.	Yield Point in Lbs. per Sq. In.	Proportional Limit in Lbs. per Sq. In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent	Maximum Fiber Stress in Lbs. per Sq. In.	No. of Cycles	Remarks
S-1	59,920	.....	21,500	25.5	55.8	25,000	1,388,000	Failure outside weld
						23,500	3,168,000	Failure outside weld
						20,000	11,503,000	No failure
S-2	64,900	.....	21,500	22.0	61.5	30,000	216,000	Failure outside weld
						28,000	2,302,900	Failure outside weld
						25,000	10,159,000	No failure
S-3	65,150	.....	23,000	22.0	62.2	25,000	1,281,800	Failure outside weld
						20,000	11,193,500	No failure
S-4	63,900	.....	24,500	17.5	61.3	25,000	1,308,910	Failure outside weld
						22,000	5,080,000	Failure outside weld
						20,000	16,298,400	No failure
S-5	56,080	.....	24,500	18.2	42.7	20,000	2,033,800	Failure outside weld
						18,000	10,000,015	No failure
S-6	63,750	33,900	21,500	20.0	63.2	22,000	3,539,600	Failure outside weld
						20,000	10,434,000	No failure
S-7	60,900	35,700	22,000	18.0	33.5	20,000	2,644,400	Failure outside weld
						18,000	10,745,800	No failure

Almost all of the data recorded in this table show a uniform relation between the different physical properties except specimen No. 2, in which case the fatigue stress does not correspond with the relatively high tensile strength obtained, giving an endurance ratio of about one-half of the average of the other specimens.

Figs. 7, 8, 9 and 10 show the grain structure X 100 of specimens Nos. 2, 3, 4 and 5 taken at the center of each fatigue specimen along the transverse section. The structures taken in this plane show a network of uniform grain size of each alloy.

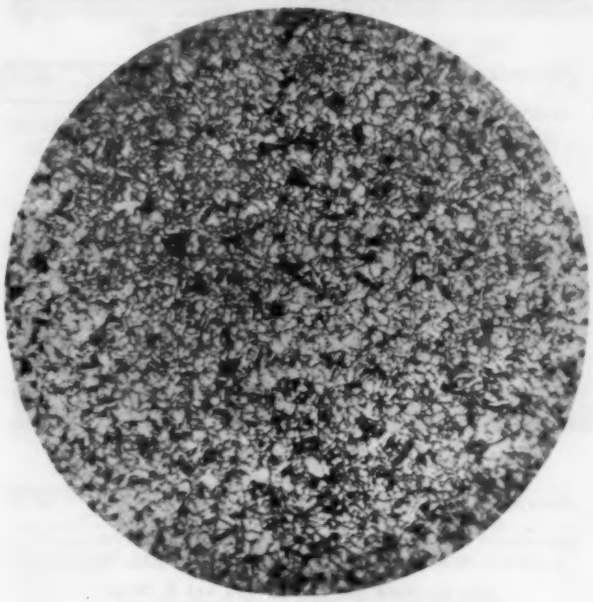


Fig. 7—All Deposited No. 2 Filler Rod

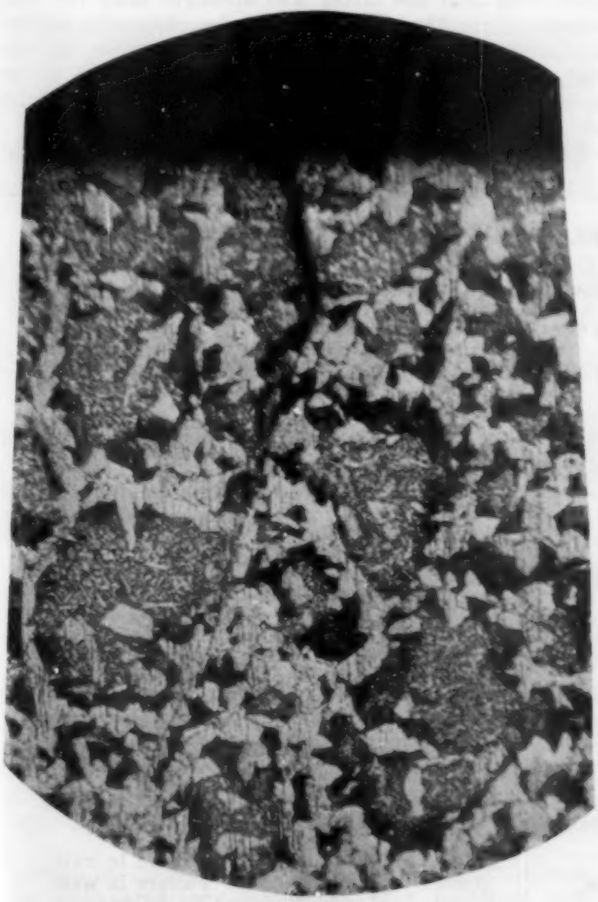


Fig. 7A—Showing Beginning of a Fatigue Crack

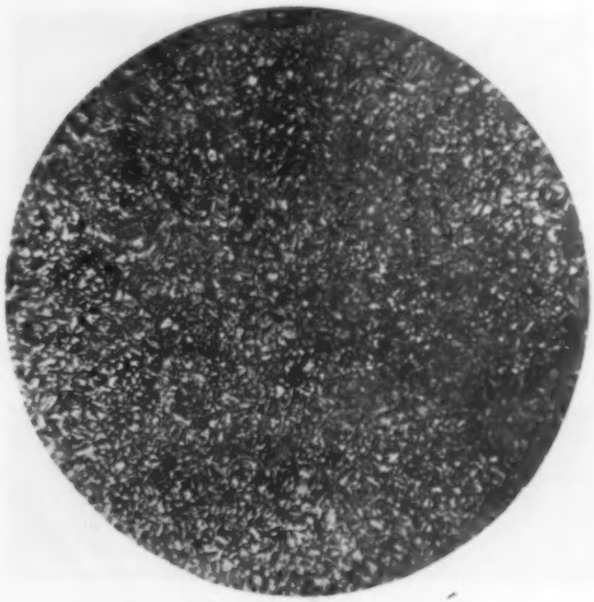


Fig. 8—All Deposited No. 3 Filler Rod

Fig. 9—All Deposited No. 4 Filler Rod

Fig. 7a is a longitudinal plane of specimen No. 2 (X 100) which shows the beginning of a fatigue crack starting at the edges of a large grain.

A discussion of the metallurgy of fatigue failures will follow in a later paper.

Tables 2 and 3 show the results of the filler metal applied to S metal and H metal in a single V weld. In these two sets of data the filler metal characteristics for each specimen are influenced by contact with the base metal.

From the plates shown in Figs. 11 to 18 inclusive it will be seen that at least one-third of the weld is made up of a mixture of filler rod and base metal. This is also shown by the Rockwell hardness tests.

In Table 3 all specimens broke outside the weld.

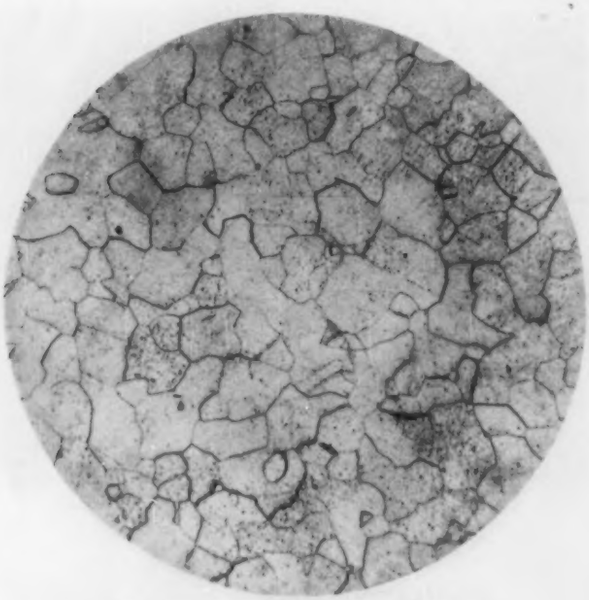


Fig. 10—All Deposited No. 5 Filler Rod

Fig. 11—Weld No. 7 Filler Rod and S. Metal

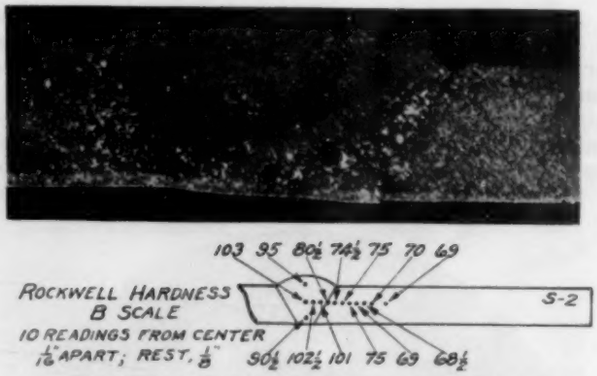


Fig. 12—Weld No. 2 Filler Rod and S. Metal

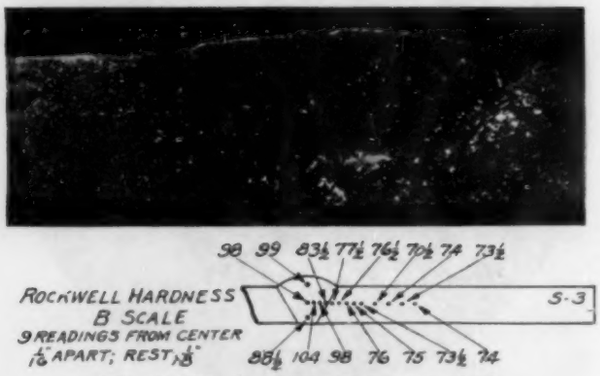


Fig. 13—Weld No. 3 Filler Rod and S. Metal

indicating that the latter was stronger than the base metal. Figs. 11, 12, 13 and 14 also show the highest Rockwell numbers to be in the weld, while immediately adjacent to it the numbers assume the characteristics of the base plate and become considerably lower than those of the weld metal.

In Table 4 all specimens broke in the weld, indicat-

TABLE 4—SINGLE V WELDS ON H METAL

Specimen	Tensile Strength in Lbs. per Sq. In.	Yield Point in Lbs. per Sq. In.	Proportional Limit in Lbs. per Sq. In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent	Maximum Fiber Stress in Lbs. per Sq. In.	No. of Cycles	Remarks
H-1	70,800	47,250	41,000	14.50	67.2	30,000	327,000	Failure in weld
						25,000	1,647,000	Failure in weld
						20,000	10,090,000	No failure
H-2	101,300	.....	39,500	6.50	33.5	40,000	91,800	Failure in weld
						35,000	1,143,000	Failure in weld
						30,000	4,165,000	Failure in weld
						25,000	10,984,000	No failure
H-3	91,000	.....	38,000	4.50	18.0	40,000	183,300	Failure in weld
						35,000	1,298,400	Failure in weld
						25,000	5,864,500	Failure in weld
						20,000	11,201,600	No failure
H-4	105,650	.....	35,000	3.20	13.2	40,000	194,000	Failure in weld
						35,000	2,621,000	Failure in weld
						25,000	15,322,000	No failure
H-5	71,050	.....	35,000	12.0	55.2	30,000	1,308,000	Failure in weld
						20,000	3,213,000	Failure in weld
						18,000	17,000,000	No failure
H-6	73,750	.....	35,000	13.20	20.4	25,000	4,494,200	Failure in weld
						20,000	11,006,200	No failure
H-7	71,300	.....	40,000	10.0	34.7	22,000	2,165,000	Failure in weld
						20,000	5,616,000	Failure in weld
						18,000	13,679,000	No failure

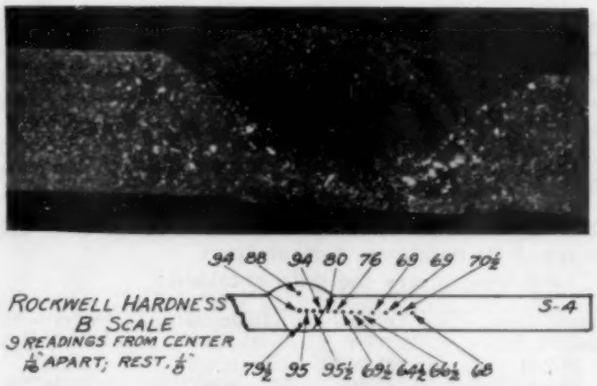


Fig. 14—Weld No. 4 Filler Rod and S. Metal

96½ 87 117 117½ 118 109½ 109 111
ROCKWELL HARDNESS
B SCALE
9 READINGS FROM CENTER
1/16" APART; REST, 1/8"
H-7
107½ 97 96½ 119 118 106 110 110

Fig. 15—Weld No. 7 Filler Rod and H. Metal

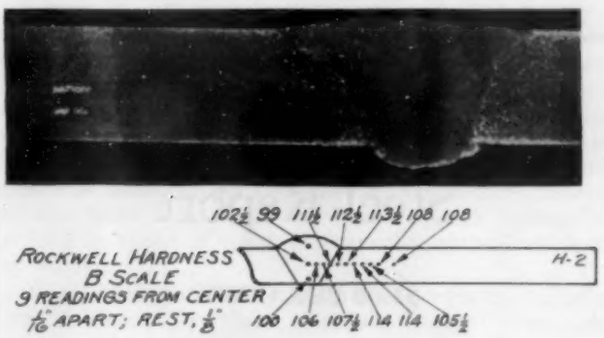


Fig. 16—Weld No. 2 Filler Rod and H. Metal

Fig. 17—Weld No. 3 Filler Rod and H. Metal

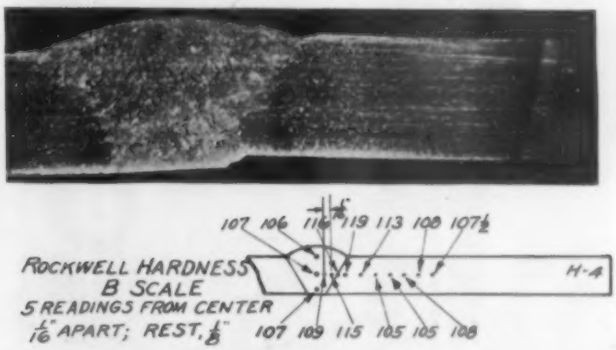


Fig. 18—Weld No. 4 Filler Rod and H. Metal

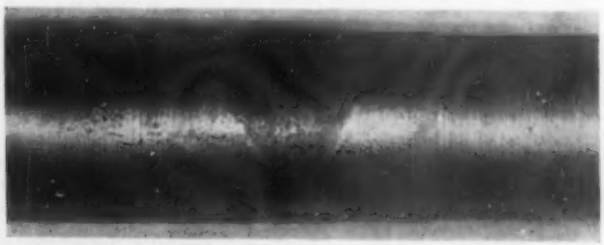


Fig. 19—Unfinished Welded Fatigue Specimen

ing it to be weaker than the base metal. In this case, Figs. 15, 16, 17 and 18 show the welds to have the lowest Rockwell numbers, building up to a maximum just outside the weld area.

The fatigue stress values for any filler rod used, such as specimens S-1 and H-1, are practically the same, although the differences in their tensile values result in corresponding differences in their endurance ratios.

Fig. 19 shows H-1 fatigue specimen after it was cut from a 1 1/16-in. thick plate and turned on a lathe to 1-in. diameter. The areas on both sides of the weld which give the higher Rockwell numbers in plate 15 have a more glossy appearance than any other part of the specimen. These areas are difficult to cut with a lathe tool on account of the difference in their hardness.

Figs. 20 and 21 show the characteristic rupture of the welded fatigue specimen. The ruptured end of the specimen shows very little reduction in area for any of the metals used in this test. A crack apparently begins on one side and travels across the specimen, transversely, covering 80 per cent of the cross-

Table 5—Analysis of Deposited Metal and Welds

Filler Rod	C	Mn	Cr	V	Si	Ni	P	S
1	0.06	0.26					All below .02	0.034
2	0.28	0.70	1.08	0.17				0.020
3	0.23	0.60				3.38		0.021
4	0.34	0.55			1.98			0.040
5	0.08	0.40						0.026
6	0.07	0.79						0.086
7	0.09	0.43						0.036
S-1	0.06	0.38						0.034
S-2	0.16	0.63	0.86	0.09				0.019
S-3	0.15	0.55				2.40		0.022
S-4	0.18	0.54			0.87			0.025
S-5	0.09	0.24						0.025
S-6	0.07	0.78						0.056
S-7	0.09	0.42						0.032
H-1	0.07	0.39						0.028
H-2	0.14	0.68	1.02	0.16				0.020
H-3	0.15	0.55				2.85		0.016
H-4	0.14	0.55			1.59			0.013
H-5	0.09	0.23						0.015
H-6	0.08	0.74						0.045
H-7	0.08	0.44						0.018

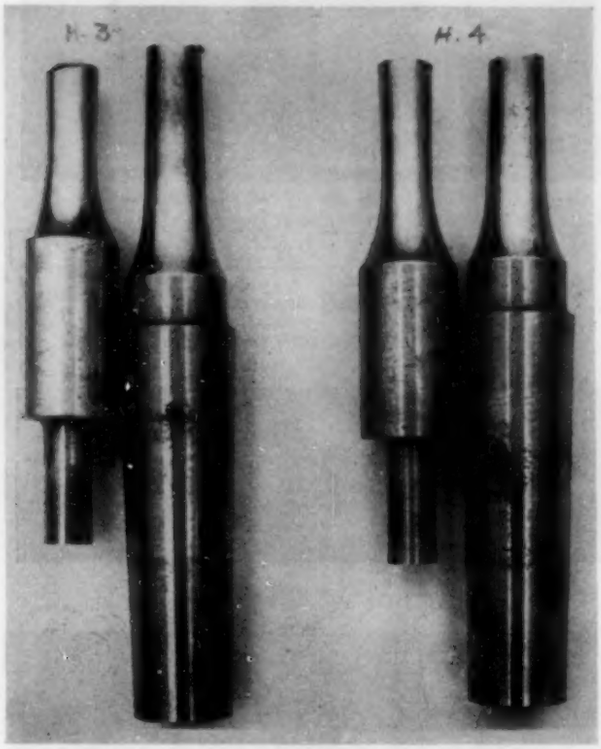


Fig. 20

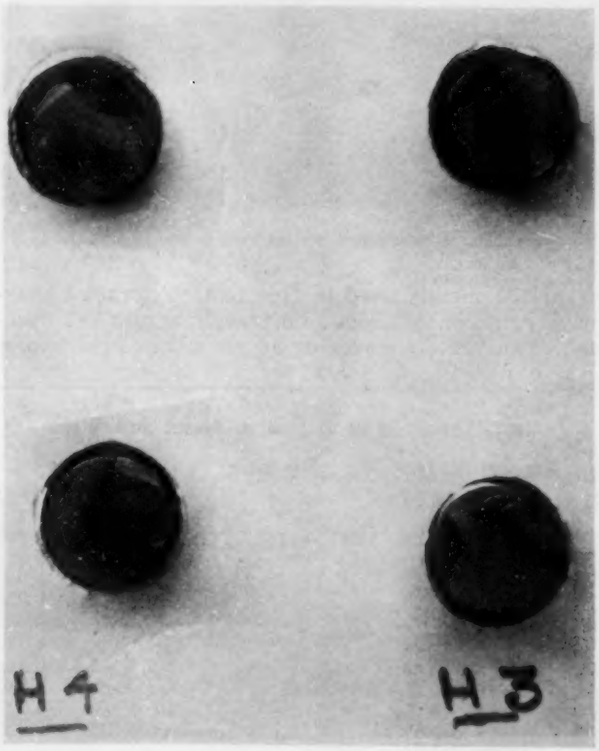


Fig. 21
Characteristic Ruptures of Welded Fatigue Specimens

sectional area, so that the remaining area then tears apart and exposes rough grain surface.

Single V welds made on 325 base metal with No. 2 filler metal (analysis given in Table 1) were made into fatigue specimens, the same as shown in Fig. 4. The end of the specimen to which the load was applied was machined smooth to provide a bearing surface for the penetometer, which was attached rigidly to the machine, and made it possible to obtain depth measurements to one ten-thousandths of an inch of the deflection of the beam while under a fatigue stress. Deflection measurements were made at the beginning of a load application and after approximately 3,300,000 cycles of stress. This was done to determine if possible any increase in deflection of the beam as it approached its maximum fatigue limit.

The following are the data obtained:

Stress, Lbs. per Sq. In.	Total Cycles	Deflection at Start	Deflection at End of Run
25,000	10,181,800	.0230"	.0230"
27,000	50,388,600	.0260"	.0260"
30,000	10,009,500	.0310"	.0310"
33,000	12,838,700	.0330"	.0330"
35,000	10,131,200	.0355"	.0355"
38,000	13,111,600	.0385"	.0385"
40,000	6,969,800	.0410"	....

The last specimen failed at 40,000 lb. per square inch stress but did not show an increase of strain beyond .0410 in. during the whole period of observation up to the time of rupture. These data would indicate first, that a specimen operating at a specific fatigue stress does not change from its immediate deformation on application of the load; second, that the deflection of the beam increased uniformly with increase in stress; third, that rupture must take place in a comparatively short time.

These results would indicate that the behavior of welded structures under fatigue stress does not differ fundamentally from that observed by previous investigators in similar tests with forged and rolled metal.

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AMERICAN WELDING SOCIETY
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A New Process of Oxy-Acetylene Welding

By T. W. GREENE

✦ Paper presented at Fall Meeting, A. W. S., September, 1931, by T. W. Greene of the Development Section, Engineering Department, The Linde Air Products Company.

PROBABLY in no other field of industrial activity today is greater progress being made than in welding. The welding industry as a whole is constantly striving for, and successfully attaining, greater joint strengths, higher weld quality with increase in rate of welding, and economy in application. In the last year or so some outstanding, almost revolutionary, developments in the field of oxy-acetylene welding have accomplished remarkable results in assurance of weld quality and economy in making oxy-acetylene welded joints.

As a result of scientific research and laboratory investigation, a new process or method, decidedly distinct in many features from previous procedures, has been evolved for manual application and accompanying this, a new welding blowpipe has been developed and perfected, which, for certain types of joints in horizontal welding, produces welds at a rate or speed of welding ranging from 3 to 3½ times faster than obtainable in the past by oxy-acetylene method and with nearly a proportional reduction in cost. This new method, which is known as the Lindeweld process, is a practical and successful application of metallurgical knowledge and skill to oxy-acetylene welding, which results in production of superior welds at a greatly increased speed. Its application in over 2000 miles of welded overland pipe line construction throughout the country, ranging in size from 4 in. to 26 in., has produced outstanding results in speed of construction, economy and efficiency of welds.

High strength welds at high speed with this welding are achieved by three interdependent, interrelated features; a special flame adjustment, the use of special welding rod and a new welding technique.

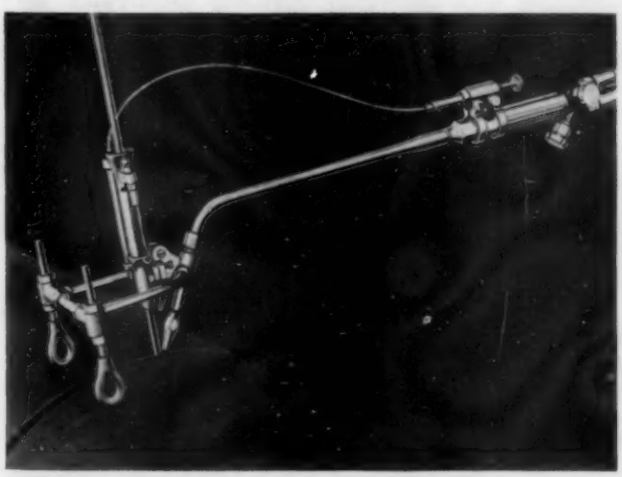


Fig. 1—New Lindewelder Blowpipe Showing Gravity Feed Welding Rod Holder

Fig. 2—New Blowpipe on 26 In. Gas Line in California

Special Flame Adjustment

The welding is done with a carbonizing flame. By virtue of certain metallurgical features of the properly adjusted flame, the weld metal is fused with the base metal through the medium of a low melting point, high carbon iron alloy.

Special Welding Rod

A new welding rod, with suitable metallurgical characteristics to produce fusion with the lower melting high carbon iron alloy surfaces, has been developed especially for this application.

Welding Technique

The welding technique recommended is in general what is known as back-hand welding, in which the flame is pointed backward against the weld. The flame and rod are manipulated more or less parallel to the line of welding. The flame is alternately played upon the base metal to prepare it for fusion and on the rod for accelerated deposition of weld metal. Very little breakdown or melting of the base metal is required with the correct procedure and, as a much smaller space can be used, due to the decrease in the contraction of the weld, an economy is effected in the amount of rod, welding gases and time required for welding.

In addition to the adaptability of the Lindeweld process to the present type of hand blowpipe, the process has been made almost automatic by the development of a special blowpipe for exclusive use with this welding method. With the use of this new blowpipe, which is called the Lindewelder, it is possible to obtain welding speeds, it is believed, equal to, or greater than those obtained with any other process. The accompanying illustration shows the essential design features of the new blowpipe. It is a two-flame blowpipe with an automatic gravity feed rod holder. A carriage having two runners supports the apparatus during the welding operation. The two flames and the rod holder are aligned in the same plane, which is also the plane of the pipe joint. The lower flame is the welding flame, which is used for preparing the base metal for proper fusion with the weld metal and for actually melting the end of the welding rod in the welding puddle. The upper flame is smaller and is used for preheating the welding rod. This preheating flame is arranged so that the

Table I—Field Welds on 20-In. Gas Line. Tensile Test

Welder & Spec. Number	Lb. per Sq. In. Yield Point	Tensile Strength	Fracture
F-1	44,700	63,200	1½" outside weld
2	42,400	62,700	2" outside weld
4	43,600	62,700	2" outside weld
5	42,400	59,600	Small lap bottom vee
S-1	42,900	64,800	1½" outside weld
2	44,200	69,500	1" outside weld
3	45,700	64,500	1" outside weld
4	44,000	64,100	1" outside weld
5	43,900	63,000	2" outside weld
6	42,500	46,300	10% poor fusion bottom vee (at spacing pin)
H-1	44,800	67,500	1" outside weld
2	46,100	65,000	Good weld
3	44,800	51,600	Slight poor fusion bottom vee
4	45,000	64,400	1" outside weld
5	45,500	64,500	1" outside weld
6	44,500	66,500	1" outside weld
B-1	43,700	66,300	1" outside weld
2	45,100	67,100	1" outside weld
M-1	41,500	65,500	Plate edge of weld

Bend Test

Spec.	Elongation, Per Cent in ½ In.	Angle of Bend (Deg.)	Remarks
M	28	180	No crack, elongation and bend test could have been carried further
S	22	180	
F	24	180	
H	24	180	
B	26	180	

inner cone impinges directly upon the rod, which is preheated to a bright cherry red, and thus little additional heat from the welding flame is required to melt it into the welding puddle. The welding operation is carried on by the back-hand method so that the completed weld is on the opposite side of the rod from the welding flame.

Development of this almost automatic blowpipe has been important in increasing efficiency and lowering costs in pipe welding. The position of the operator during the welding is such that he may work with a minimum of fatigue and a maximum of comfort. In welding the joint the operator stands or sits at the side of the pipe facing the joint. This position is possible for all pipe sizes and also for horizontal tank welding. Since only one hand is required to hold the blowpipe, the operator is free to make any necessary adjustments to the flame, change the rod, signal the turner, or, if he wishes, shift the blowpipe to the other hand without any interruption to the welding operation. Another advantage in the position assumed by the operator is that as the welding progresses toward him he can see both sides and the bottom of the vee at all times so as to control the quality of the weld.

All adjustments necessary for the operation of the blowpipe may be made by the operator's right hand. A lifting device controlled by a trigger on the blowpipe handle permits the operator to raise or lower the welding rod as required in starting, passing over tack-welds, changing rod and in finishing. The possible travel of

Table II—Physical Properties of Welds Made with Lindewelder

Pipe Size and Wall Thickness Carbon, Per Cent	Welding Tips	Welding Time of Joint, Minutes	Coupon No.	Tensile Strength, Lb. Sq. In.	Fracture	Elongation in ½ In., Per Cent	Elongation in 1 In., Per Cent	Angle of Bend, Deg.	Type of Failure, Bend Test
20"	11 & 4	14¾	1	77,000	Outside 2"	26	24	...	Crack
5/16"			2	78,500	Outside 2"	26	21	152	Crack edge
Wall			3	77,000	Outside 1"	32	26	135	Crack weld
.25-.35C			4	77,500	Outside 1"	26	22	111	Crack weld
			T	74,500	Outside grips				
	Average			76,900		28	24	133	
20"	12 & 5	13½	1	78,000	Outside 2"	24	20	90	Broke
5/16"			2	80,000	Outside 1½"	28	17	65	Crack
Wall			3	77,000	Outside 1"	32	31	180	No failure
.25-.35C			4	78,000	Outside 1"				
	Average			78,000		28	23	112	
20"	11 & 5	16	1	78,400	Outside 2"	28	24	98	Crack
5/16"			2	51,500	Weld section liner lug not fused	36	33	160	Crack
Wall			3	76,300	Weld bottom not fused	30	21	75	Broke
.25-.35C			T	79,500	Outside 2"				
				74,400	Weld—one blowhole				
	Average			72,000		31	26	111	
24"	11 & 5	20½	1	99,400	Edge weld	26	16	56	Broke
5/16"			2	100,200	Weld good	24	13	53	Broke
Wall			3	96,500	Outside 2"	21	11	45	Broke
.30-.40C			2	97,000	Outside 3"				
			1	83,400	Weld small defect bot.				
	Average			95,300		23	13	51	
16"	11 & 5	11	1	49,000	Outside weld	20	25	180	No failure
¼" wall			2	50,700	Outside weld	30	32	180	No failure
low carbon	Average			49,800		25	29	180	

All welds made with Lindeweld flame. Coupon numbers indicate quadrant of joint from which coupon was selected at random: T coupon from tack; F coupon from finish of weld.

NOTE: Bend test made on specimens 1½" wide with reinforcement ground off. Pin bend test made with pin ¾" diam., with specimen supported on 1½" rollers, 3½" on center with clear distance between rollers 2".

the lifter is about 2½ in., giving the operator perfect control of the rod, which is free to feed into the weld when the lifter trigger is forward, and is gripped by the device when the lifter trigger is pulled back.

The manipulation or technique required with this blowpipe is very simple; in fact, it is almost automatic. The welding is always under the instant control of the operator. Practically the only manipulation required is a slight raising or lowering of the handle. By lowering the handle the main welding flame is brought to impinge more directly on the base metal in order to prepare it more quickly for fusion; by raising the handle the flame impinges more directly on the rod, accelerating rod deposition when desired, thus producing a controllable and efficient balance between preparation and welding rod deposition. Fig. 2 shows the use of this blowpipe on a 26 in. gas line. The particular blowpipe shown in the illustration is one of the earlier models which does not have the rod lifting device. With this model the rod is lifted and lowered by hand.

As an indication of the speed of welding that has been attained in field application, production or number of rotated welds per day per welder on some lines has been increased three to four times over that secured on similar size lines following former procedures for pipe line construction. The time for making 20 in. pipe joints, 5/16 in. wall, on one large line where the new blowpipes have been used with the Lindeweld process, varied from 14 to 19 minutes, with an approximate average of 16 to 17 minutes per weld. The rate of welding attainable with this blowpipe is so fast that production is dependent primarily on efficiency of organization and personnel. On a 26 in. gas line a maximum production per welder of 25 joints has been obtained in a nine hour day.

The increased speed has not been accomplished at sacrifice of quality. The figures referred to are those attained in making welds of full strength and maximum quality. This can be seen from results of field tests, Table I, a typical day's tests of welds, selected at random, cut from a 20 in. line for inspection of workmanship and check of the weld quality.

Table II shows the weld quality secured on the full range of commercial pipes, varying in carbon content from the ordinary low carbon pipe (0.05-0.20 per cent carbon) to the upper practical limit of 0.35-0.40 per cent carbon. Although the pipe strengths vary from 50,000 lb. per sq. in., the average for low carbon pipe, to over 100,000 lb. per sq. in. for higher strength material, welds of full strength with remarkable ductility were readily obtained.

When these uniform high strengths and weld qualities are considered in connection with the marked increase in speed and saving of welding materials, the new process and the new blowpipe may well be considered the most important recent development.

The Welding of Copper and Brass Pipe

By H. V. INSKEEP

†This paper was presented at the A. W. S. Fall Meeting, September, 1931, by H. V. Inskeep, of the Development Section, Engineering Dept., Linde Air Products Co.

THE past few years have seen a great increase in the use of copper and brass pipe. Its applications for the most part have been found in the water distribution systems of buildings. Copper and brass pipe have been giving good service, both in regard to long life and freedom from rust in the distribution of water to plumbing fixtures, particularly where rust stains are objectionable. The inherent advantages of copper and brass pipe and the advertising campaigns which are bringing its good features before the public will undoubtedly greatly increase the use of these metals for piping systems.

Conventional types of mechanical joints: the screwed coupling, the screwed flange and the Van Stone joint, have been used up to the present time on most installations. However, just as the mechanical joint has not given perfect service in steel and iron piping systems this type of joint has not proved entirely satisfactory for copper and brass pipe. Even greater difficulty in obtaining satisfactory joints in copper and brass pipe is experienced because of the characteristics of these metals. Accurate threads are difficult to cut in both of these metals, and extreme care has to be taken to produce a good joint, large pipe particularly, requiring great care. Even with good workmanship and careful inspection joints do not make up properly and joint compounds, and in some cases cotton cords, have to be used in the base of the threads as the joint is turned up. The Van Stone joint, having no threads, produces a satisfactory joint and is easily pulled tight. It has usually been used on important work. Its high cost is its main disadvantage.

Unlike steel and iron, copper and brass do not rust or corrode to close permanently any leaks which may exist or become existent when the line is put into service. Hence great care must be exercised to see that the joints are tight under test, and the line be free from expansion and other stresses which are liable to disturb the joints. However, perfect freedom from stresses is not possible, especially in lines that are carrying hot water or other liquids at high temperatures. The alternate heating and cooling of such lines produces different rates of expansion and contraction between the pipe and the coupling, and eventually a leak may develop which will not corrode shut. As a result of these characteristics there has been some hesitancy by engineers to specify copper or brass pipe for tunnels or other places where the joints are not easily accessible. Experience has shown that maintenance on such lines is often difficult and expensive. However, there is one solution for this problem, the substitution of the welded joint for the mechanical joint.

Copper and brass present a different welding problem from the welding of steel which is easily controlled under the welding flames. They are more fluid when in the molten conditions and are apt to be more difficult to handle in position welding. These conditions made necessary a special consideration of the welded joint for these metals.

In an effort to determine the best type of joint and

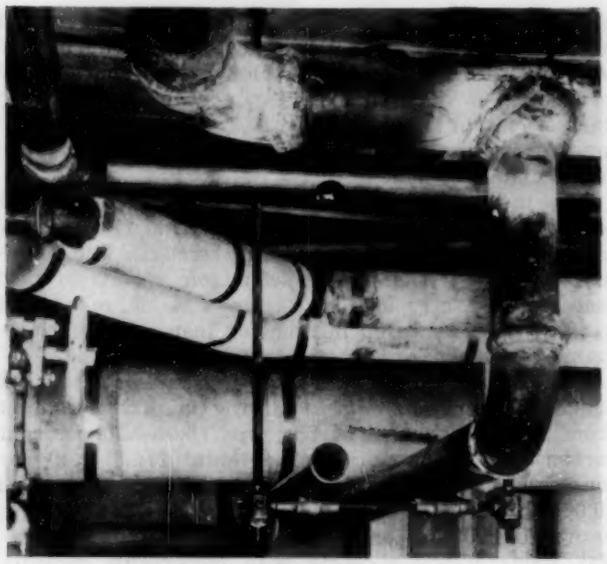


Fig. 1—Bronze-Welded Brass Hot Water Lines, 4-In. Line Is Shown With 3-In. Outlet and 2-In. Line With 1½-In. Outlet

the best welding procedure to follow in welding brass pipe and copper tubing, the Union Carbide and Carbon Research Laboratories has conducted an extensive research program. This investigation was made chiefly because it was thought that the butt joint could not give desired full strength and is not the easiest joint to make in the field. Experiments were conducted on different sizes of pipe and tubing; using the butt joint, the short bell and spigot joint and the long bell and spigot joint. The investigation included commercial red brass pipe, alpha brass pipe, Muntz metal pipe and copper tubing. Several types of welding rod were used, including ordinary bronze rod, high strength bronze rod and copper rod. Some trials were also made using the pipe material itself as a welding rod.

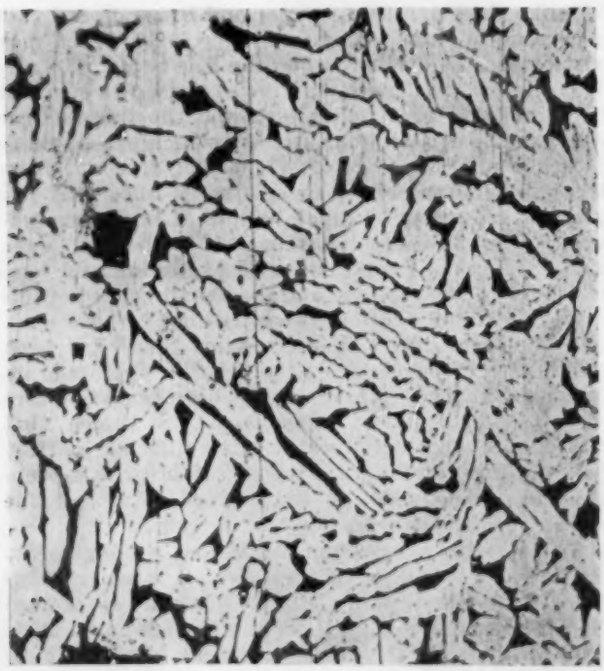


Fig. 2—Photomicrograph of Welded Joint Between High Strength Bronze Weld Metal and Muntz Metal Pipe; a Fusion Weld With No Change in Structure at the Joint

It was realized at the outset that the ideal welded joint for this class of materials and the services for which they are used would have to fulfill four conditions:

1. The joint must be smooth on the inside of the pipe without requiring an extraordinary amount of skill on the part of the welding operator to obtain this condition.
2. The joint must possess the full strength of the pipe material if possible.
3. It must be possible to produce a satisfactory joint in all welding positions.
4. The joint must be neat in appearance. This condition may be sacrificed if the other three are obtained without it.

To meet these conditions the bell and spigot joint was designed and a comparison made between it and the butt joint on all the materials welded.

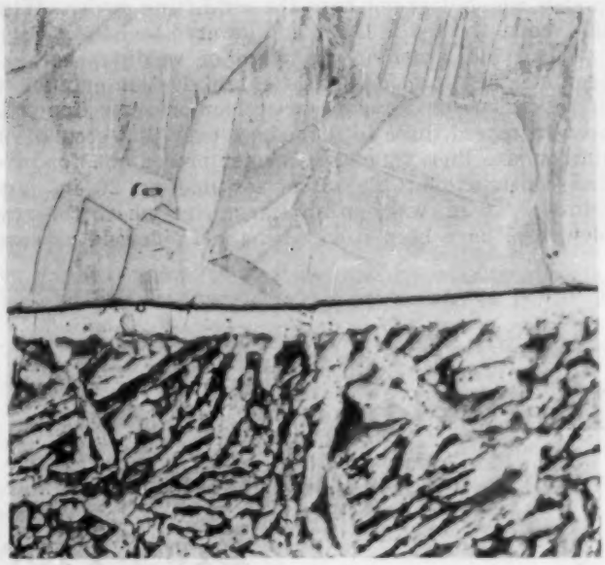


Fig. 3—Photomicrograph of Welded Joint Between High Strength Bronze Weld Metal and Alpha Brass Pipe; it is a Bronze-Welded Joint

The results of tests on red brass pipe will first be considered. Its composition was approximately 85 per cent copper and 15 per cent zinc. In the 1-in. size thirteen joints were made: Six were welded in the vertical position, two of which were short bell and spigot, two with the long bell and spigot and two with the butt joint. High strength and ordinary welding rod were used on each type of joint. Seven specimens were welded in the horizontal position: two short bell and spigot joints with high strength rod and one with ordinary rod, two long bell and spigot joints with high strength, and two butt joints using each type of rod.

In the vertical position all short and long bell and spigot joints broke in the inserted pipe at the edge of the weld, at a strength of approximately 38,000 lb. per square inch, the strength of the material in the annealed condition. The two butt joints both broke in the weld metal at slightly over 15,000 lb. per square inch. In the horizontal position the results were the same, with the exception that the short bell and spigot joint welded with ordinary rod broke in weld metal at 29,000 lb. per square inch. The butt welds were of higher strength, 32,800 and 25,400 lb. per square inch for the high strength and the ordinary rod respectively. Since this set of experiments showed that there

ALPHA BRASS PIPE

Type	Position	Welding Rod	Ultimate Strength	Fracture
Short Bell	Vertical	High Strength	33,800	In pipe metal next to weld
Short Bell	Vertical	High Strength	33,500	In pipe metal next to weld
Butt	Vertical	High Strength	18,350	In weld metal
Butt	Vertical	Ordinary	25,300	In weld metal
Short Bell	Horizontal	High Strength	36,500	In pipe metal next to weld
Short Bell	Horizontal	High Strength	31,200	In weld metal
Butt	Horizontal	High Strength	38,400	In pipe metal next to weld
Butt	Horizontal	Ordinary	36,000	In pipe metal next to weld

Muntz Metal Pipe

Short Bell	Vertical	High Strength	35,800	Next to weld
Short Bell	Vertical	Ordinary	31,200	Next to weld
Long Bell	Vertical	High Strength	43,400	Base metal 1 in. from weld
Long Bell	Vertical	Ordinary	32,700	Next to weld
Butt	Vertical	High Strength	23,600	In weld metal
Butt	Vertical	Ordinary	17,500	In weld metal
Short Bell	Horizontal	High Strength	38,400	Next to weld
Short Bell	Horizontal	Ordinary	35,800	Next to weld
Long Bell	Horizontal	High Strength	40,900	Base metal ½ in. from weld
Long Bell	Horizontal	Ordinary	40,900	Base metal ½ in. from weld
Butt	Horizontal	High Strength	35,600	Next to weld
Butt	Horizontal	Ordinary	36,650	Next to weld

¾-In. Copper Water Tubing

Bell	Vertical	High Strength	28,750	In inserted pipe at edge of weld
Bell	Vertical	Ordinary	29,800	In inserted pipe at edge of weld
Bell	Vertical	Copper	23,400	In weld metal
Butt	Vertical	High Strength	29,800	In pipe at edge of weld
Butt	Vertical	Ordinary	27,150	In weld and pipe
Butt	Vertical	Copper	28,750	1½ in. from weld
Bell	Horizontal	High Strength	29,800	In inserted pipe at edge of weld
Bell	Horizontal	Ordinary	29,800	In inserted pipe at edge of weld
Bell	Horizontal	Copper	29,250	In inserted pipe at edge of weld
Butt	Horizontal	High Strength	29,250	In inserted pipe at edge of weld
Butt	Horizontal	Ordinary	28,200	In inserted pipe at edge of weld
Butt	Horizontal	Copper	28,750	In inserted pipe at edge of weld

1½-In. Copper Water Tubing

Type	Position	Welding Rod	Ultimate Strength	Fracture
Short Bell	Vertical	High Strength	32,650	In inserted pipe at edge of weld
Short Bell	Vertical	Copper	32,400	In inserted pipe at edge of weld
Long Bell	Vertical	High Strength	30,900	In inserted pipe at edge of weld
Long Bell	Vertical	Copper	24,000	In weld metal
Butt	Vertical	High Strength	21,100	In weld metal
Butt	Vertical	Copper	25,700	In weld metal
Short Bell	Horizontal	High Strength	31,500	In inserted pipe at edge of weld
Short Bell	Horizontal	Copper	32,100	In inserted pipe at edge of weld
Long Bell	Horizontal	High Strength	32,650	In inserted pipe at edge of weld
Long Bell	Horizontal	Copper	32,400	In inserted pipe at edge of weld
Butt	Horizontal	High Strength	32,100	In inserted pipe at edge of weld
Butt	Horizontal	Copper	25,400	In weld metal

1-In. Red Brass Pipe

Short Bell	Vertical	High Strength	38,200	In inserted pipe at edge of weld
Short Bell	Vertical	Ordinary	37,000	In inserted pipe at edge of weld
Long Bell	Vertical	High Strength	39,050	In inserted pipe at edge of weld
Long Bell	Vertical	Ordinary	39,300	In inserted pipe at edge of weld
Butt	Vertical	High Strength	15,850	In weld metal
Butt	Vertical	Ordinary	15,420	In weld metal
Short Bell	Horizontal	High Strength	39,050	In inserted pipe at edge of weld
Short Bell	Horizontal	High Strength	38,450	In inserted pipe at edge of weld
Long Bell	Horizontal	High Strength	38,900	In inserted pipe at edge of weld
Long Bell	Horizontal	High Strength	38,650	In inserted pipe at edge of weld
Short Bell	Horizontal	Ordinary	29,400	In weld metal
Butt	Horizontal	High Strength	32,800	In weld and pipe
Butt	Horizontal	Ordinary	25,400	In weld metal

2½-In. Red Brass Pipe

Short Bell	Vertical	High Strength	38,400	In inserted pipe at edge of weld
Short Bell	Vertical	High Strength	37,200	In inserted pipe at edge of weld
Short Bell	Vertical	Ordinary	25,900	In weld metal
Butt	Vertical	High Strength	14,600	In weld metal
Butt	Vertical	Ordinary	13,200	In weld metal
Short Bell	Horizontal	High Strength	30,600	In inserted pipe at edge of weld
Short Bell	Horizontal	High Strength	35,200	In inserted pipe at edge of weld
Short Bell	Horizontal	Ordinary	22,200	In weld metal
Butt	Horizontal	High Strength	21,800	In weld metal
Butt	Horizontal	Ordinary	17,800	In weld metal

seemed to be little advantage in the use of the long bell and spigot joint, at least where the high strength rod was used, in the set of experiments on the 2½-in. pipe only the short joint was used.

In the 2½-in. size ten specimens were welded, five in the vertical position and five in the horizontal. Three short bell joints were welded in each set, two with high strength rod and the other with ordinary rod. Two butt joints in each set were welded using each type of rod. The two short bell and spigot joints in each set welded with the high strength rod broke in the pipe metal at its full strength in the annealed conditions, averaging about 36,500 lb. per square inch. The short bell and spigot joints welded with ordinary rod broke in the weld metal at 25,900 and 22,200 lb. per square inch for the vertical and horizontal positions respectively.

The alpha brass pipe, with a composition of approximately 67 per cent copper and 33 per cent zinc, gave similar test results. One-inch pipe was used in these tests. Eight specimens were tested. Two short bell joints welded in the vertical position broke in the pipe metal next to the weld at a strength of about 33,000 lb. per square inch. The two butt joints welded in this position broke in the weld metal, the high strength rod specimen breaking at 18,350 lb. per square inch and the ordinary rod specimen at 25,300 lb. per square inch. In this case a better quality weld happened to be produced with the low strength rod. One of the short bell joints welded in the horizontal position broke in the pipe metal next to the weld at 36,500 lb. per square inch and the other broke in the weld metal at 31,200 lb. per square inch. The two butt welds made in this position broke in the pipe metal at 38,400 and 36,000 lb. per square inch for the high strength rod and ordinary rod respectively.

The Muntz metal pipe test produced slightly different results in that only the long bell joints developed the full strength of the annealed material. The composition of this pipe was approximately 62 per cent copper and 38 per cent zinc, and the size of the specimens was 1 in. The strength of the long bell joints may be accounted for by the slight eccentricity of the short bell cross section and the difficulty experienced in preventing under-cutting in this material, as it is nearly of the same melting point as the welding rods used. All four of the long bell joints broke in the pipe metal at strengths over 40,000 lb., with the exception of one which broke at 32,700 lb. per square inch. The butt welds for the vertical position broke in the weld metal at 23,600 and 17,500 lb. per square inch for the high strength and the ordinary rod respectively. In the horizontal position they broke next to the weld at 35,600 and 36,650 lb. per square inch for the high and low strength rods respectively.

It is seen from these results that the short bell and spigot joint consistently gave strengths approaching that of the parent metal in the condition as annealed by the welding flame. It also gave full strength in all vertical welds which, it was found, could not be expected of the butt joint. The long bell and spigot joint gave the same results, except that this type is slightly better on Muntz metal. However, the increase in strength obtained with this joint would not justify the expense necessary to produce it. The short bell and spigot joint is more easily made both in the field and in the shop. In the field a tapered plug driven with a sledge will quickly form the flare on the end of the pipe for the insertion of the beveled end. Pipe in the larger sizes can be ordered with the short bell joint prepared at only slightly higher cost than the conventional beveling at 45 deg. Beveling in the field is done by means of a file or a thread-cutting machine fitted with a cutting tool.

The short bell joint has met conditions number one in that there can be no projections on the inside of the pipe. Condition number two is met as shown by the data obtained from the tests and listed in the accompanying table. Condition number three has been met as just explained. Condition number four is fulfilled as the bell joint is not unsightly and a really good appearance can be obtained in all positions with ordinary skill and care. It became apparent from examination of the data and the fractured welds that the high trength rod was the most satisfactory to use. Experimental welds made with the pipe material for rod were porous and of poor quality generally. No attempt was made to do an extraordinarily good job of welding as field conditions were wanted, and it is believed that these same results can be duplicated by the average brass welder.

The experiments to determine the most satisfactory joint for copper tubing were conducted in the same manner. Two sizes of tubing were used, ¾-in. and 1½-in. The same conditions had to be met as in the case of pipe, and the bell and spigot joint was used in comparison with the butt joint. Copper welding rod was used for these tests as well as the welding rods used for the preceding tests. To avoid quoting detailed data it is sufficient to say that both the bell and the butt type of joints gave full strength in the ¾-in. size wih the exception of one bell joint welded with copper which broke in the weld metal at 23,000 lb. per square inch. All the rest of the specimens averaged over 29,000 lb. per square inch.

The 1½-in. tubing showed about the same results, with the exception that the vertically welded specimens showed three low strength welds out of the total of six. One of these was a long bell joint welded with copper welding rod and broke in the weld at 24,000 lb. per square inch. The other two were butt welds, one welded with high strength welding rod which failed at 21,000 lb. per square inch and the other welded with copper welding rod which failed at 25,700 lb. per square inch. Two short bell and one long bell joints failed in the tube at an average ultimate strength of about 30,980 lb. per square inch. In the horizontally welded specimens the results were more uniform, all but one of them failing in the tubing at an ultimate of over 30,000 lb. per square inch. One butt weld made with copper rod failed in the weld metal at 25,400 lb. per square inch. Here, again, the bell type of joint was the best from a strength standpoint, and as the short bell is most easily made, it should be used. Also no projections are possible with this type of joint, a major consideration for tubing of this small size. The extremely difficult vertical weld is made with ease, and full strength is obtained in this position.

In conclusion it may be said that this investigation has indicated the worth of a joint designed to make the welding of brass and copper pipe and copper tubing easier and provides for the production of uniformly high strength welds in all positions. An actual installation, totaling about 90,000 lb. of red brass pipe in sizes up to 5 in. in diameter, in which this type of joint was specified by the engineer and installed by the contractor, has shown that the advantages determined in the laboratory have been realized in the field.

REPORT OF STRUCTURAL STEEL WELDING COMMITTEE

—FOREWORD—

In a comparatively short time the art of fusion welding by the arc and gas processes has developed into one of the important tools in the metal industry. Due to the incessant efforts of research and industry, welding methods and procedure have been improved, equipment has been developed, a sufficient number of experienced welders have been trained and become available, and the dependability and safety of welding has been established. In the field of structural steel, fabrication and erection have been making marked advances the world over.

This report of the Structural Steel Welding Committee is the result of an investigation extending over a period of five years which had for its principal object the determination of stresses that may be safely used in the designing of welded steel structures fabricated under ordinary commercial fabricating shop conditions. Much other information was, however, developed as may be readily inferred from the volume of this report.

The investigation is, and was intended to be, intensely practical. Tolerances in workmanship of a kind that must be anticipated in commercial work, were purposely allowed by the Committee. Naturally the tests show greater variations in result than are usual in more academic research. This fact, while it has rendered precise analysis more difficult, is believed to greatly increase the reliance that can be placed on the findings as to what may be expected in commercial practice.

The aim has been to complete the report in accordance with the plans laid out by the late James H. Edwards. As its first Chairman, Mr.

Edwards organized the Committee in 1926 and from that time up to his death in August, 1930, his vigorous and sane personality was reflected in every phase of its work. He took a keen interest in the planning of the many technical details involved, and he insisted that all matters should be excluded that did not appear to be of direct and practical value to structural steel designers and fabricators.

Linked with the work of Mr. Edwards, appreciation is recorded for other special assistance made possible by the officials of the American Bridge Company of which he was Chief Engineer. Both prior to and following Mr. Edwards' death, this Company permitted Mr. H. M. Priest, one of its assistant engineers, to devote much time to the work of the Committee. Mr. Priest was responsible for carrying out all the work described in this report under the heading "Administration," as well as for many contributions in fields described in other sections of the report.

The services of Mr. Milton Male were employed for the detailed tabulation, charting and analysis of the results of the investigation. The able manner in which Mr. Male handled this part of the work is reflected in the report.

To these men as well as to each member of the Committee the success of the investigation is to be credited.

This extensive investigation was made possible through the generous support and cooperation of the companies and individuals listed under "Acknowledgments." The Committee takes pleasure in expressing, on behalf of all interested in the progress of the welding art, its appreciation of that cooperation.

LEON S. MOISSEIFF
Chairman

ABSTRACT OF REPORT

This report constitutes a complete record of the activities to date of the Structural Steel Welding Committee of the American Bureau of Welding—a Committee organized in 1926 for the purpose of "obtaining reliable information upon which to base safe unit working stresses in the designing of welded structures."

After reviewing all of the test data in the literature available at that time (see summary published in the American Welding Society Journal, November, 1927), the Committee concluded that a comprehensive series of tests should be made before final recommendations were promulgated.

An investigation was therefore undertaken, the principal objects of which, after some modifications during the progress of the work, were the determinations of:

1. Safe design values under static loading for various types of fusion welded joints as commercially welded in structural steel fabricating shops.
2. The degree of uniformity of the strength of welded joints that may be expected from such shops throughout the country.

In order that the results of the investigation would be thoroughly representative of commercial practice, a large number of shops were invited to participate. To insure the maximum uniformity of procedure in the conduct of the tests, comprehensive instructions were prepared covering all details from the selection of the welders to the preparation of test reports by the cooperating laboratories.

The final program, as carried out and reported herein, included the welding and testing of 1,098 specimens in connection with the qualification of the welders and 1,395 specimens in connection with the investigation proper—the latter involving 55 elemental forms of joint in 169 sizes.

The participants in the investigation included three steel mills, 39 fabricating shops, 61 welders, 18 inspectors, and 24 testing laboratories. The work was distributed over the central and eastern portions of the United States. A Canadian laboratory provided pilot or preliminary information based on the testing of 342 specimens welded in three Canadian shops. About five years have been spent on the entire investigation.

The final conclusions of the Committee with respect to its two principal objects of investigation, are:

1. The following permissible unit stresses, in kips (thousands of pounds) per sq. in. of weld throat, specified in the American Welding Society's "Code for Fusion Welding and Gas Cutting in Building Construction":

Shear	11.3
Tension	13.0
Compression	15.0

   are safe and reasonable, and are indorsed, provided the welder has been qualified and provision has been made for bending stresses that may be introduced due to eccentricity.
2. In commercial practice a welded joint may be expected to have a strength within 12 per cent of a general average for that type of joint, provided the welder has attained the stated qualifications.

The important requirement in that Code with reference to making adequate provision for bending stresses due to eccentricity can be met in a practical manner by a division of joints into two classes —those having negligible and those having considerable eccentricity. Simple characteristics are given in this report whereby a proper classification may be made.

This report points out that the Committee's conclusions are necessarily based on the behavior of the particular specimens investigated, and with a view to extending the scope of its conclusions a number of desirable fields for further research are recommended.

ACKNOWLEDGMENTS

In order to carry out the proposed program the Committee determined that its principal requirements would be:

1. The sum of $22,500 to defray the expense of the investigation.
2. Approximately 54 tons of standard structural steel.
3. At least 36 representative fabricating shops to weld the program specimens.
4. A corps of competent inspectors to supervise the welding of the qualification specimens.
5. A number of conveniently located laboratories to test the specimens.

The Committee was successful in meeting these requirements with the generous and whole-hearted cooperation of a number of organizations and individuals, both within and outside of the welding industry.

been spent on the entire investigation.

organizations and individuals, both within and outside of the welding industry.

The required funds were contributed by:

a. THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION.

b. The following individual members of the NATIONAL ELECTRIC MANUFACTURERS ASSOCIATION.

Electric Arc Cutting & Welding Co.
General Electric Company
The Lincoln Electric Company
Northwestern Manufacturing Co.
Westinghouse Elec. & Mfg. Co.
Wilson Welder and Metals Co.

c. The following individual members of the COMPRESSED GAS MANUFACTURERS ASSOCIATION, GAS ASSOCIATION, GAS PRODUCTS ASSOCIATION and INTERNATIONAL ACETYLENE ASSOCIATION.

Acetylene Products
Acme Oxygen Company
Air Reduction Company
Burdett Oxygen & Hydrogen Co.
Commercial Acetylene Company
Commercial Gas Company
Compressed Gas Corporation
Gas Products Association
Gas Products Company
General Welding & Equipment Co.
Harris Calorific Company
Imperial Brass Manufacturing Co.
International Acetylene Assn.
International Oxygen Company
K-G Welding Company
Keith Dunham Company
Kentucky Oxygen-Hydrogen Co.
Magnolia Gas Products Company
Modern Engineering Company
National Gauge & Equipment Co.
Pressed Steel Tank Company
Shawinigan Products Company
Torchweld Equipment Company
Union Carbide & Carbon Company.
Universal Oxygen Company

The steel was donated and freight charges paid, by:

Bethlehem Steel Company	Bethlehem, Pa.
Carnegie Steel Company	Pittsburgh, Pa.
Illinois Steel Company	Chicago, Ill.

The welded specimens were, with one exception, prepared without charge by these 39 shops:

American Bridge Company	Ambridge, Pa.; Gary, Indiana; *Minneapolis, Minn.; Trenton, N. J.
Belmont Iron Works	Philadelphia, Pa.
Berlin Construction Company	Berlin, Conn.
Bethlehem Steel Company	Bethlehem, Pa.
Carolina Steel & Iron Company	Greensboro, N. C.
Electric Arc Cutting & Welding Company	Newark, N. J.
General Electric Company	Schenectady, N. Y.
Genesee Bridge Company	Rochester, N. Y.
Hub Steel Company	Detroit, Mich.
Hutton Welding Company	Jersey City, N. J.
Indiana Bridge Company	Muncie, Ind.

*Reimbursed for cost of welding.

Kansas City Structural Steel Company	Kansas City, Kan.
Leake & Nelson Company	Bridgeport, Conn.
Linde Air Products Company	Buffalo, N. Y.
McClintic-Marshall Company	Pittsburgh, Pa.
Minneapolis Steel & Machinery Company	Minneapolis, Minn.
Mississippi Valley Structural Steel Company	Decatur, Ill.
Mt. Vernon Bridge Company	Mt. Vernon, Ohio
Nashville Bridge Company	Nashville, Tenn.
Paxton & Vierling Iron Works	Omaha, Neb.
Phoenix Bridge Company	Phoenixville, Pa.
Providence Steel & Iron Company	Providence, R. I.
Pullman Car & Manufacturing Corporation	Pullman, Ill.
Republic Structural Iron Works	Cleveland, Ohio
Rochester Welding Works	Rochester, N. Y.
Rock Island Bridge & Iron Works	Rock Island, Ill.
Slaymaker Electric Welding Company	Detroit, Mich.
Smith & Caffrey Company	Syracuse, N. Y.
A. L. Smith Iron Works	Chelsea, Mass.
Stupp Brothers Bridge & Iron Company	St. Louis, Mo.
Superior Welding Company	Detroit, Mich.
Virginia Bridge & Iron Company	Roanoke, Va.
Westinghouse Electric & Manufacturing Co.	Pittsburgh, Pa.
Whitehead & Kales Company	Detroit, Mich.
Wisconsin Bridge & Iron Company	Milwaukee, Wis.
Worden-Allen Company	Milwaukee, Wis.

The welding of the qualification specimens was supervised without charge by:

INSPECTOR	AFFILIATION	NUMBER OF SHOPS SUPERVISED
H. J. Bowles	Bethlehem Steel Company	1
R. W. Clark	General Electric Company	5
H. M. Downing	The Lincoln Electric Company	1
C. T. Eakin	Westinghouse Electric & Manufacturing Co.	3
H. P. Egan	The Lincoln Electric Company	1
A. H. Friese	The Lincoln Electric Company	2
L. P. Henderson	The Lincoln Electric Company	1
Manuel Hufferd	Kansas City Structural Steel Company	1
H. V. Inskeep	Linde Air Products Company	2
C. E. Loos	American Bridge Company	3
E. Lunn	Pullman Car & Manufacturing Corporation	1
A. D. McCarthy	Hub Steel Company	1
J. H. Merz	Paxton & Vierling Iron Works	1
H. M. Priest	American Bridge Company	6
J. M. Robinson	The Lincoln Electric Company	2
R. K. Slaymaker	Slaymaker Electric Welding Company	1
William Spraragen	American Bureau of Welding	4
M. J. Wall	Linde Air Products Company	1

The specimens were tested by:

(Entire Cost of Testing Contributed)

Robert W. Hunt Company	Chicago, Illinois
Norfolk & Western Railway	Roanoke, Virginia
Pittsburgh Testing Laboratory	Pittsburgh, Pa.
Milton Male	(Student, Massachusetts Institute of Technology)
Gerald C. Ward	(Student, University of Wisconsin)

(Cost of Handling Reimbursed at Fixed Rate Per Specimen; Cost of Supervising and Reporting Tests Contributed)

Brown University	Providence, R. I.
Carnegie Institute of Technology	Pittsburgh, Pa.
Case School of Applied Science	Cleveland, Ohio
Cornell University	Ithaca, N. Y.
Lehigh University	Bethlehem, Pa.
Massachusetts Institute of Technology	Cambridge, Mass.
Ohio State University	Columbus, Ohio
Perry Testing Laboratory	Detroit, Mich.
Princeton University	Princeton, N. J.
Purdue University	Lafayette, Ind.
Rensselaer Polytechnic Institute	Troy, N. Y.
Stevens Institute of Technology	Hoboken, N. J.
United States Bureau of Standards	Washington, D. C.
University of Kansas	Lawrence, Kan.
University of Minnesota	Minneapolis, Minn.
University of North Carolina	Chapel Hill, N. C.
University of Pennsylvania	Philadelphia, Pa.
University of Pittsburgh	Pittsburgh, Pa.
Washington University	St. Louis, Mo.
Yale University	New Haven, Conn.

PILOT TESTS

Appreciation of the generous cooperation of those who carried out the valuable pilot tests conducted at Toronto, Canada, in 1927 and 1928, is here re-acknowledged. This work, already reported in the March, 1929, issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY, was done without any expense to the Committee by:

Peter Gillespie	University of Toronto
C. A. Hughes	" " "
K. B. Jackson	" " "
J. H. Fox	" " "
Canadian General Electric Company	Toronto, Canada
Dominion Oxygen Company	" "
McGregor and McIntyre	" "
Drummond McCall & Company	" "

The necessary funds were supplied by:

School of Engineering Research	University of Toronto
National Research Council	Ottawa, Canada

SECTION 1

INTRODUCTION

1-1 HISTORICAL BACKGROUND

The World War provided a stimulus for remarkable developments in methods of uniting metals by means of welding. The first important application of these newer methods was in shipbuilding, followed by major applications in such fields as pipe-work, pressure vessels and machinery. The notable success that attended these applications caused members of the American Welding Society, during the years immediately preceding 1926, to consider the suitability of welding processes, particularly fusion welding, in the field of structural steel.

A small number of buildings had already been erected, or were being contemplated, in which the steel frame-work was connected by means of welded joints. At that time only a very few, even of the larger shops, had made any study of welding practice. Predicated on the construction being done by one of these few concerns, the engineers in charge of design had undertaken preliminary tests on which to base the strength of joints in each particular structure. No general values for working stresses could be based on such uncoordinated and unrelated tests. An imperative need was perceived for authoritative values that could be used in the design of any structure welded by any responsible concern.

1-2 EXISTING TEST DATA

In those industries where welding had already been established, a first requirement was that the welded joint should, if possible, be stronger than the base metal. As a basis for the design of such joints, several thousand tests had been made on specimens designed with this aim. In most of these specimens the joints were of butt-form with continuous weld. These tests indicated that a weld might be stronger than a certain value, but its absolute strength was not disclosed.

It seemed evident that joints of a fillet form were better suited to the types of connection usually required in structural work. It was further realized that in most structural framing it was not necessary, and in some cases not economical, to utilize all the edges or corners available for welding; for example, in plate girders, the connections of web to flanges, and of the separate parts of flanges to each other. This indicated the desirability of using intermittent welds. Before welding could be generally applied to the design of

School of Engineering Research . . . University of Toronto
National Research Council . . . . Ottawa, Canada

This indicated the desirability of using intermittent welds. Before welding could be generally applied to the design of

framed structures the strength of welded joints, of both butt and fillet form, had to be determined on some unit basis which would permit the design of welds of any size or length.

Test data on fillet welds were very meager, and practically no tests had been made on intermittent welds. The limited extent of the information that was available at that time is evident from a progress report of this Committee published in the November, 1927, issue of the Journal of the American Welding Society. Such data were manifestly insufficient to form a basis for the establishment of standard design values.

1-3 FORMATION OF COMMITTEE

To obtain reliable information upon which safe unit working stresses could be based, the Structural Steel Welding Committee of the American Bureau of Welding* was organized in the Fall of 1926 and held its first meeting on November 17th at Buffalo, N. Y.

During the organization period of the Committee it was learned that the Research Committee of the American Institute of Steel Construction** was contemplating a somewhat similar investigation. The Institute very graciously merged its proposed work with that of the Committee and has cooperated in the present investigation to the fullest degree. It contributed a large part of the required funds; it canvassed its membership for shops willing to weld the proposed specimens; and its representatives rendered valuable personal assistance in the councils of the Committee.

To carry out its work, the following Sub-Committees were appointed: Ways and Means, Literature on Tests, Materials and Tests, and Welding Procedure. At a later date a small Executive Committee was formed and authorized to act on such matters as did not require submission to the whole Committee.

1-4 ORIGINAL AIMS OF COMMITTEE

Its organization accomplished, the Committee decided tests were needed that would:

1. Confirm or modify previous results by the use of a larger number of specimens, and a more uniform system of testing.
2. Supplement the scope of previous data by tests on additional forms of joint.
3. Determine what degree of uniformity in commercial welding may be expected.

*An Advisory Board on Welding Research and Standardization of the American Welding Society and the Division of Engineering of the National Research Council.

**An organization embracing over 200 fabricating shops and construction companies located in the United States, Canada and Mexico.

The degree of uniformity could be determined by distributing the work among a large number of shops over a large geographical area.

With such data the structural designer would be able to determine safe working stresses for all sizes and forms of welded joints. The factor of safety used would depend on the extent to which minimum values in the specimens tested varied from their average.

1-5 CONTEMPORARY DEVELOPMENTS

During the progress of this investigation the welding art has not marked time. Welding equipment and the technique of its use and control have been continuously improved, and there has been a decided advance in the development of welding wires of high quality and strength. Were this investigation to be carried out under present conditions, the results undoubtedly would reflect this advance.

The American Welding Society in 1928 formulated and published a "Code for Fusion Welding and Gas Cutting in Building Construction" in which the following permissible unit stresses are specified in kips* per square inch on a section through the weld throat:

Shear	11.3
Tension	13.0
Compression	15.0

A large number of welded structures have been erected since 1926 in the design of which these unit stresses have been used with satisfactory results. The 1930 Edition of the Code made no changes in these unit stresses. The most common weld in structural work is the $\frac{3}{8}$-inch fillet, and it has become almost standard practice to use a working value for such a fillet, in static shear, of 3 kips per linear inch, equivalent to 11.3 kips per sq. in. of throat area, and to use proportional values for other sizes.

Another development was the increasing recognition of the importance of competency on the part of the welder and that more reliable welders could be secured by subjecting each welder to specific qualification tests.

1-6 REVISED AIMS OF COMMITTEE

In view of these developments, the Committee decided to study the test results from the standpoint of values being used, and to simplify the application of these values by a classification of forms of joint. The aims of the Committee, therefore, were revised to include the determination of:

1. The forms of joint to which existing values are applicable.
2. The forms of joint in which these values should be modified.

*A kip is one thousand pounds

3. The extent to which a welder's qualification tests are reflected by his subsequent performance.
4. What degree of uniformity in commercial welding may be expected.

1-7 CONVENTIONS AND RULES USED IN REPORT

In the presentation of the report the rules given below have been followed:

(1) All test results have been interpreted along the most conservative lines.

(2) A high degree of legibility in tabular and charted matter has been the aim rather than excessive consolidation.

(3) Acknowledgments to participants have been made in alphabetical sequence.

(4) An identifying symbol has been given to each shop. All specimens prepared by the shops are referred to by shop symbol instead of name. It is possible for the reader to determine which specimens were prepared by the same welder, but means of identifying the shop which employed that welder are purposely withheld.

(5) Loads and stresses are expressed in kips. The term *Kip* has been extensively used in technical literature to designate *one thousand pounds* and is employed here as being terse and convenient.

(6) *Roundings.*

Loads and unit stresses are given to the nearest tenth of a kip.

Weld lengths are given to the nearest tenth of an inch.

Welding time is given to the nearest minute.

(7) Wherever applicable, the nomenclature used conforms to that recommended by the American Welding Society Committee on Nomenclature, Definitions and Symbols.

In the original Specifications, fillet welds in longitudinal and transverse shear are referred to as in parallel and normal shear, respectively. For the sake of brevity in the text of this report, they are referred to as side and end welds.

(8) The Dewey Index System has been adopted for ease of reference.

SECTION 2

PROCEDURE

2-1 TABULATION OF EXISTING TEST DATA

Before considering the design of program specimens a comprehensive survey was made of all available literature which contained pertinent test data. These data were summarized and published by the Committee in the November, 1927, issue of the Journal of the American Welding Society.

From the information contained in that summary, probable maximum ultimate strengths of a number of forms of joint were estimated. These values served as a guide in designing the program specimens.

2-2 DESIGN OF PROGRAM SPECIMENS

The intent was to proportion specimens so that failure would occur in the weld and thus indicate unit weld strength. For check purposes a few groups were included that were expected to fail in the base metal. It was known that welds could generally be made strong enough to cause failure in the base metal, as had been done in many previous tests.

Drawings were made and tables prepared showing the ultimate load to which each specimen would be subjected. With a view to simplification, the bar sizes were limited to five tentative widths, 3, 4, 5, 8 and 12 inches, with thicknesses varying by eighths of an inch.

2-2-1 CAPACITIES OF AVAILABLE TESTING MACHINES

By correspondence with a number of laboratories information was compiled as to the capacities of testing machines and the sizes of bars that could be accommodated in their jaws. This information is reproduced in Table I.

As a result of this preliminary information and of suggestions from a number of laboratories to which the tentative designs had been submitted, the 8-inch and 12-inch bars were changed to 7½ and 11½ inches, respectively, in order that those specimens might be more conveniently handled in the machines. The lengths of the grip, or c* bars, were increased so as to extend to the back of the grips.

*In all specimens, the grip bars and center bars were designated c and b, respectively. See Section 5-5, Table VI; and sketches in Appendix 10-4.

increased so as to extend to the back of the grips.

*In all specimens, the grip bars and center bars were designated c and b, respectively. See Section 5-5, Table VI; and sketches in Appendix 10-4.

TABLE I

CAPACITIES OF TESTING MACHINES AS OF MAY 15, 1931

Laboratory	Max. Capacity in Tension Kips	Maximum Size of Specimen		Width of Grips Ins.
		Width Ins.	Thickness Ins.	
Brown University	400	7½	3	4
Carnegie Inst. of Technology	400	5½	1⅞	4
Case School of Appl. Science	200	4	...	...
Cornell University	300	4	2	4
Hunt, Robt. W. Company	300	8	3	4
Lehigh University	800	6	5	6
Massachusetts Inst. of Tech.	400	8	4½	4
Ohio State University	1,000	12	5	7
Perry Testing Laboratory	150	6	2	4
Pittsburgh Testing Lab'y	600	8½	3½	6
Princeton University	200	3⅜	2½	3⅜
Purdue University	300	3⅞	2	3⅞
Rensselaer Polytechnic Inst.	600	8	3	5
Stevens Inst. of Technology	100	....	1	3
U. S. Bureau of Standards	1,150	11½	2¼	8
University of Kansas	200	3½	2¼	3½
University of Minnesota	400	6	2¾	4
University of No. Carolina	200	5	3½	...
University of Pennsylvania	600	8	3	5
University of Pittsburgh	200	6	2	6
University of Wisconsin	200	6	1½	3½
Washington University	200	3½	1¼	3½
Yale University	150	5	1½	5

2-2-2 PILOT TESTS AT TORONTO

The investigation involved the preparation of rather elaborate instructions in order that the final results of work done in widely separated shops should be reasonably comparable.

Because of the magnitude of the program and the somewhat complex nature of its proposed instructions the Committee thought it desirable to make a preliminary trial of the specifications. Knowledge was needed as to the behavior of certain unusual forms of joint, as well as information as to how the instructions would be interpreted.

The late Professor Peter Gillespie of the University of Toronto very kindly undertook the testing of 342 specimens selected from the original list. The Committee's rules of

procedure were faithfully followed through all the steps from the qualification of welders to the testing and reporting of the specimens. The results of these trial pilot tests were reported in the University's Research Bulletin No. 8, Section No. 2, and in the March, 1929, issue of the Journal of the American Welding Society.

2-2-3 DIGEST OF "SPECIFICATIONS" PUBLISHED JULY, 1928*

As a result of these pilot tests certain changes were made in the instructions and in the design of a few specimens, as will be brought out in other parts of this report. Soon thereafter, in July, 1928, the Committee published its "Specifications for Test Specimens: Their Preparation and Testing," comprising six sections, viz: (A) General Information, (B) Qualification of Welders, (C) Welding Specifications for Test Specimens, (D) Inspection and Supervision, (E) Design of Program Specimens (originally called "Test Specimens"), and (F) Procedure for Testing.

As these Specifications are now out of print a general digest of the essentials of each section will be given here. Further details will be given in connection with those items in the Specifications which bear upon the subjects treated.

SECTION A—GENERAL INFORMATION

This Section contained a statement of the purpose for which the Committee was organized, a reference to the summary and publication of existing test data, and the aims of the Committee.

The scope of the original program, as there outlined, covered 57 forms of joint in 191 sizes welded by the gas or arc process. . . . Specimens were of elemental type and embraced fillet welds of lap and tee form, end and edge butt welds, and special joints. Single and double lines of weld, normal, parallel, and diagonal to the direction of stress, continuous and intermittent, were specified. Entire members were to be considered later.

As actually carried out, the investigation covers 55 forms of joint, herein called "series," in 169 sizes, herein called "specimen groups." All specimens have been subjected to static test only, for the determination of ultimate strength, and of yield point where possible.

SECTION B—QUALIFICATION OF WELDERS

This section set forth the procedure to be followed in qualifying the arc and gas welders designated by the shops to weld the specimens. The details of this section are given in this report in Section 2-4, Qualification Tests.

*These Specifications were reproduced in the November, 1928, issue of the Journal of the American Welding Society.

SECTION C—WELDING SPECIFICATIONS FOR PROGRAM SPECIMENS

This Section covered the following items: (1) Grade of Steel, (2) Preparation for Welding, (3) Position of Specimen during Welding, (4) Filler Metal (Electrodes and Welding Rods), (5) Preparatory Tacking, (6) Welding Arc, (7) Welding Gas Flame, (8) Gaging Welds, (9) Heat Treatment (none), (10) Identification Marks, (11) Packing of Specimens for shipment to Laboratory, (12) System for Marking Specimens. These items are discussed in detail in Section 2-5, Fabrication of Program Specimens.

SECTION D—INSPECTION AND SUPERVISION

This Section outlined the duties of the Inspectors. They were primarily to conduct the preliminary or qualifying tests of welders, and to inspect the material and witness the welding of the program specimens.

Information was given illustrating the several factors which determine the physical characteristics of welds. Those for arc welds were: current, arc voltage, depth of penetration, overlap, and appearance of deposited metal. Those for gas welds were: cleanliness of tip, arrangement of hose and other welding facilities, flame characteristics, penetration, impurities in deposited metal, appearance of deposited metal.

Forms were provided for recording in detail the information desired by the Committee. Forms 100, 101, and 102 were for qualification specimens, Forms 103 and 104 for program specimens.

SECTION E—DESIGN OF PROGRAM SPECIMENS

This Section comprised information regarding the design of the program specimens. In Appendix 10-4 of this report the essential data are reproduced. The general welding instructions have been consolidated on page 125. Series designations have been changed where necessary to conform to the recommendations of the Committee on Nomenclature, Definitions and Symbols of the American Welding Society. None of the original data have been changed.

A note on the Cover Page of Section E stated: "The lengths of weld shown in the diagrams of this Section are net effective lengths. No weld shall start or end more than ¼ inch beyond the effective length." The significance of this note is pointed out in Section 4, Adjustment of Length and Cross-Section.

SECTION F—PROCEDURE FOR TESTING

This Section was divided into two parts—(1) Tests of Materials and Tests of Specimens, (2) Laboratory Equipment and Methods of Testing. The various items covered by these headings are summarized in Section 2-6, Testing of Program Specimens.

2-3 ADMINISTRATION

2-3-1 BAR STEEL

The required bar steel in identical lists was supplied by the Bethlehem Steel Company, the Carnegie Steel Company, and the Illinois Steel Company. From the shipping bills of the mills it was possible to ascertain the heat numbers of the different sizes of bars sent to the shops. The mills furnished the Committee with the physical and chemical data pertaining to each heat, and for check purposes sent standard A.S.T.M. coupons for tensile test to the United States Bureau of Standards.

These data are reported in Appendix 10-1. In Appendix 10-4, heat numbers are indicated for all specimens welded by shops included in the original program. Shops XA and DR, which joined in the program at a later date, furnished bar material conforming to Specification A.S.T.M. A-9 from local sources, and such action is indicated in Appendix 10-4 by the absence of heat numbers or by the notation "own stock."

2-3-2 ALLOCATION OF SPECIMENS

2-3-2-1 **A. I. S. C. Questionnaire**—From replies to a questionnaire sent to its members by the American Institute of Steel Construction, supplemented by offers from several non-members, a list of fabricating shops which expressed a willingness to weld specimens for the Committee was secured. For several months the details of supplementing the tentative information obtained by the questionnaire were carried on by correspondence, until the required number of shops were secured.

2-3-2-2 **Assignment of Specimens**—The location of the three steel mills naturally suggested three divisions of territory (I, II and III), each mill supplying the steel for one division. When placing a shop into a division two considerations were kept in mind:

1. Proximity of the shop to the mill, in order to minimize freight charges.
2. Accessibility of the shop to Committee headquarters for administrative purposes.

The geographical distribution of the shops and mills, as shown in Fig. 1, extends over the northeastern portion of the United States. Divisions I, II and III each contained 12 "assignment groups." Each shop was allotted an assignment group except that in Division II, the four assignment groups, 5, 6, 7, and 8, were distributed among eight shops, each taking half a group.

Program Specimens.

groups, 5, 6, 7, and 8, were distributed among eight shops, each taking half a group.

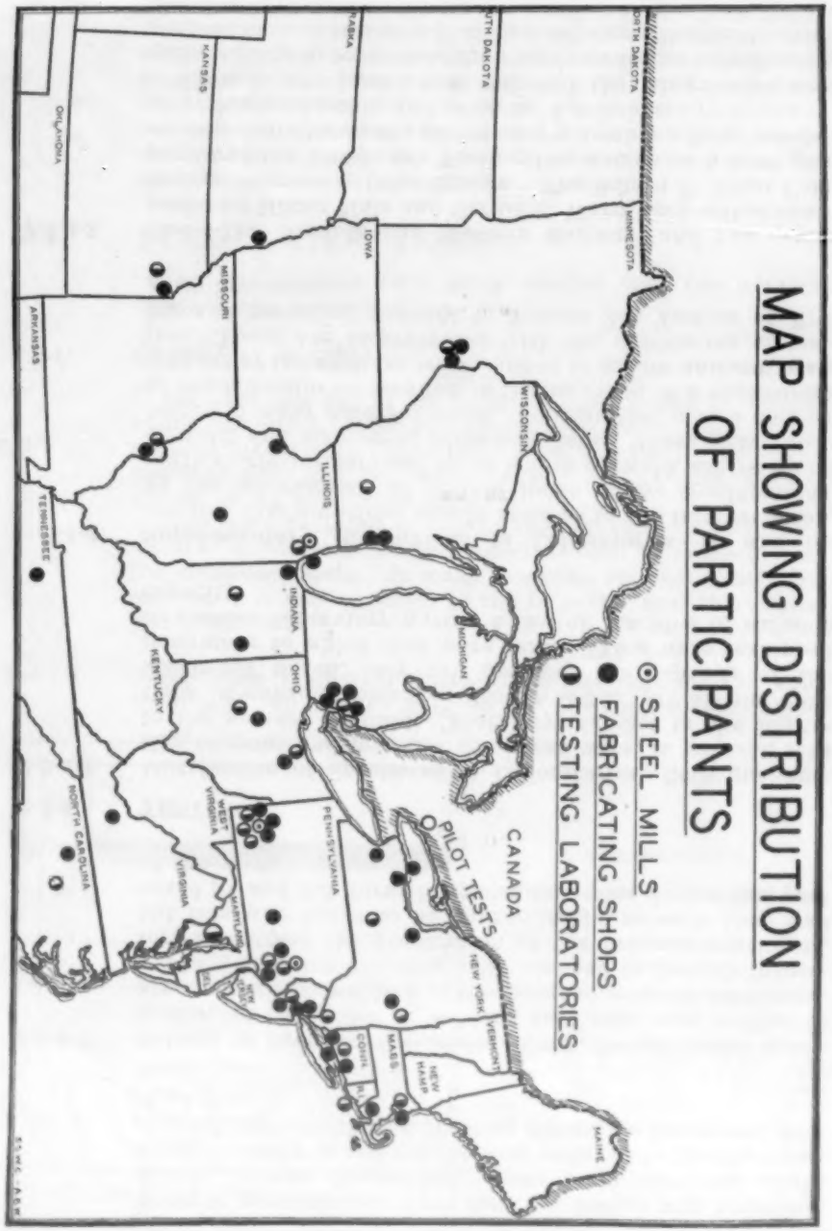


FIG. 1—GEOGRAPHICAL DISTRIBUTION OF PARTICIPANTS

In one case, where it was necessary to re-assign an allotment of specimens, the only available plant was owned by a fabricating company that had already prepared three assignments. The Committee deemed it proper to reimburse this plant for the actual cost of the added work. With this exception all specimens were prepared without charge by the fabricating shops.

The specimens assigned to each group in the same division varied both in number and design, but the same numbered group in each of the three divisions welded identical specimens. Since a minimum of three specimens is usually considered desirable for test purposes, it was decided to schedule three specimens of each size in each division, thus providing a total of nine specimens of each size. In the case of Series 2100 and 2300, which typify frequently used joints, this number was increased to 18. Such a group of 9 or 18 identical specimens is termed a "specimen group."

2-3-2-3 **Shipping and Cutting Lists**—After the specimens had been apportioned among the 39 shops the following were prepared:

1. Mill orders giving size and lengths of all bars to be rolled.
2. Shipping lists of bars for each assignment group.
3. Shop cutting lists for the bars. In ordering bars no allowance had been made for waste in cutting. A list, therefore, was sent to each shop in order to ensure correct cutting. Otherwise the shop might have drawn material from stock of whose physical and chemical analysis the Committee would have no record.

2-3-3 INSPECTION AND QUALIFICATION

2-3-3-1 **Inspectors**—Arrangements were made to secure skilled inspectors to qualify welders at the shops. Upon advice that the steel had been received from the mill, an inspector was assigned to conduct the tests. In a few cases where difficulty was encountered in securing an inspector, because of the distance and consequent travel involved, it was found necessary to expedite the work by permitting the shop's own welding foreman or supervisor to act as inspector. Blank forms were provided upon which to record all information desired by the Committee.

2-3-3-2 **Qualification and Approval**—As will be shown in Section 2-4, Qualification Tests, the most important feature of these tests was the welding of five sets of plates to be tested in tension after being cut into coupons. The coupons were sent to a laboratory designated by the Committee and blank forms were furnished upon which to record the test data.

When received, the reports of the laboratory and the inspector were examined by a sub-committee. If the specified

strength requirements were met, the welder was approved, if not, he was disqualified. Some cases involving slight non-conformity in test results were referred to the Chairman of the Sub-Committee on Welding Procedure for special consideration.

2-3-3-3 **Release of Program Specimens**—Upon the successful qualification of its welder or welders, each shop was notified to proceed with the welding of the assigned program specimens.

The Committee had originally planned to furnish inspectors to witness the preparation of the program specimens, but this was found to be impracticable, so each shop was asked to, and did, furnish its own inspector during this part of the work.

2-3-4 TESTING

2-3-4-1 **Distribution of Specimens to Laboratories**—Both qualification coupons and program specimens were, in general, sent to the nearest available laboratory, subject to the limitations in capacity noted in Section 2-2-1. Of all the 1395 specimens tested, only two exceeded the capacity of the laboratory to which they were sent. These were reshipped to another laboratory having a testing machine of suitable capacity.

2-3-4-2 **Supplementary Instructions to Laboratories**—It was inevitable that questions should arise as to the interpretation, by the laboratories, of certain items in the specifications, particularly instructions as to length of weld, cross-section of weld, and manner of recording data. These were interpreted in many different ways. Consultation with a number of the laboratories resulted in the issuance of a supplementary set of instructions which aimed to secure uniform practice. These are incorporated with the description of testing and reporting methods in Section 2-6, Testing of Program Specimens.

2-3-4-3 **Cost**—The Norfolk and Western Railway, and two senior students, Milton Male and Gerald C. Ward, each tested qualification coupons without charge. The Robert W. Hunt Company and the Pittsburgh Testing Laboratory each most generously contributed the entire cost of testing a large number of both qualification and program specimens.

While it was known that many of the laboratories were quite willing to contribute their services for an investigation such as this, it was felt that in most cases the funds available for such purposes were too small. At the U. S. Bureau of Standards the services of a Research Associate were paid for to cover all testing charges.

In arranging for the cooperation of the University Laboratories the following basis of reimbursement was adopted to partially cover the manual labor costs involved:

Width of Grip Bar	Fee per Specimen
11½″	$5.00
7½″	4.00
5″	3.00
4″ and 3″	2.00
2″ Qual. Coupons	1.00

2-3-5 TECHNICAL ASSISTANT

When sufficient results had accumulated to make possible a study of the data, the services of a technical assistant to the Committee were secured. The scope of his work, performed under the direction of the Executive Committee, covered the compilation and arrangement of data, the preparation of charts, graphs and tables, analysis of data, and the preliminary draft of the report.

2-3-6 GENERAL OBSERVATIONS

2-3-6-1 **Time Taken by Investigation**—Nearly five years elapsed after the organization of the Committee before the data were available for study. The principal factors affecting the time required to complete the program were the qualification of welders and the fabrication of the program specimens. Some of the shops to which assignments had been made were having difficulty in keeping up to schedule time on contract work. This resulted in delaying the work of preparing the specimens for the Committee, which with the exception of one shop (Section 2-3-2-2) was being done gratuitously.

It finally became necessary to set October 1, 1930, as the date after which no further specimens would be accepted for inclusion. This date was later extended to meet a special case, and the last specimens were shipped to the laboratory January 14, 1931. The final reports from the laboratory were received by the Committee March 4, 1931.

2-3-6-2 **Need for Simplification**—As originally planned, the program called for the collection of very comprehensive data on many features of welded joints. In the attempt to carry out the work along the proposed lines it was soon found that simplification was imperative if the major aims were to be achieved. It was, therefore, decided to expedite the work by relieving both shops and laboratories of all unnecessary burden in the preparation of specimens and the recording of data.

Had the full original program been attempted, it is believed that its details would have crowded out the important aims of the Committee.

of Standards the services of a Research Associate were paid for to cover all testing charges.

lieved that its details would have crowded out the important aims of the Committee.

2-3-6-3 **Concentration of Administrative Control**—Experience in directing the work has led to the conclusion that the administration of an investigation as extended as this, from the standpoint of geographical territory, detail, and duration, should be vested in the hands of not more than one or two persons who should be responsible for carrying the investigation through its many ramifications. Any other method must result in confusion and delay.

2-4 QUALIFICATION TESTS

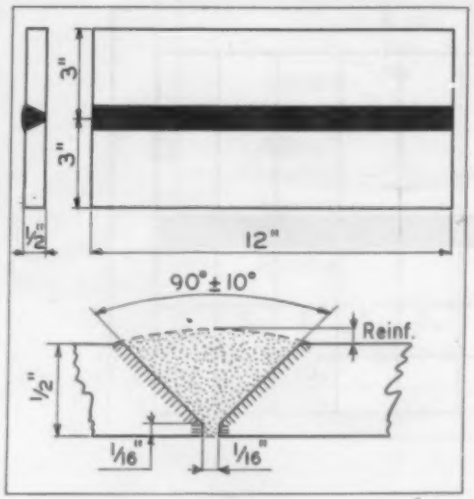
The qualification tests were divided into two classes, optional and mandatory.

2-4-1 OPTIONAL TESTS

The carrying out of the optional tests might be waived at the discretion of the inspector. These tests were recommended for welders whose experience was limited or whose previous work had been of a different nature than that involved in the mandatory tests.

They were included to enable the inspector to determine whether a welder possessed sufficient skill to proceed with the mandatory tests. In many cases the optional tests were omitted if it was apparent to the inspector that the welder was proficient.

2-4-1-1 **Observation Test (Gas Only)**—This test required the butt welding of two plates similar to Fig. 2. The material might



SPECIFICATIONS

Reinforcement — 20% of plate thickness.

Minimum speed per hour: 2 ft. Flat, 1¼ ft. Vertical.

Position of specimen during welding: Flat or Vertical.

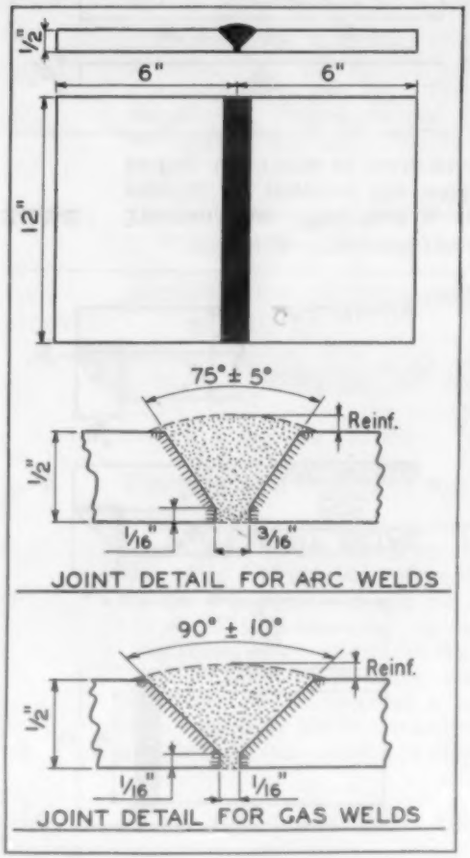
Note: Plates shall be firmly clamped to a suitable support and must be properly spaced to allow for contraction of joint during welding

FIG. 2—SPECIMEN FOR OBSERVATION TEST [GAS WELDERS ONLY]

be pieces of scrap plate of structural steel quality. The specifications accompanying the figure indicate what was required of the welder.

The purpose of this test was to permit the inspector to observe the manner in which the welder manipulated his torch and welding rod.

2-4-1-2 **Vise Test (Arc and Gas)**—This test required the welding of one or more specimens similar to Fig. 3. Scrap plates were permitted here also. They were welded in a flat position. Upon completion and after cooling, coupons were cut therefrom as shown in Fig. 4. The use of gas was permitted in cutting these coupons.



SPECIFICATIONS

Single Vee butt joint welded one side only.

Penetration—100%.

Reinforcement — 20% of plate thickness.

Position of Joint—Flat.

FOR ARC WELDERS

No. of weld layers—2.

Amperes—Approx. 200.

Size of Electrode—3/16".

Note: Before welding the plates shall be tack welded at the ends of the joint.

FOR GAS WELDERS

Speed—Not less than 2 ft. per hour.

Note: Plates shall be firmly clamped to a suitable support. Plates must be properly spaced to allow for contraction of joint during welding.

FIG. 3—SPECIMEN FOR VISE TEST

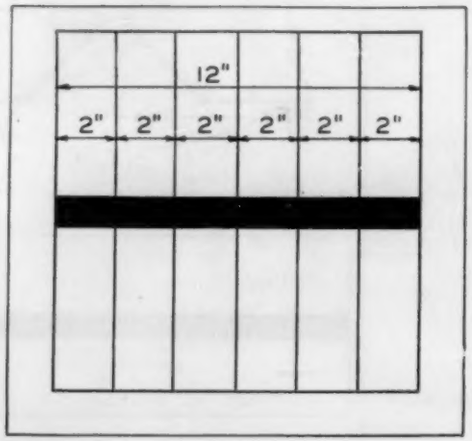


FIG. 4
COUPONS FOR VISE TEST

Each coupon was then placed in a bench vise so that the top of the vise jaws gripped the center line of the weld longitudinally. By striking the upper end with a sledge so as to produce tension at the root of the weld, the coupon was bent until the weld fractured or until the coupon could no longer be bent.

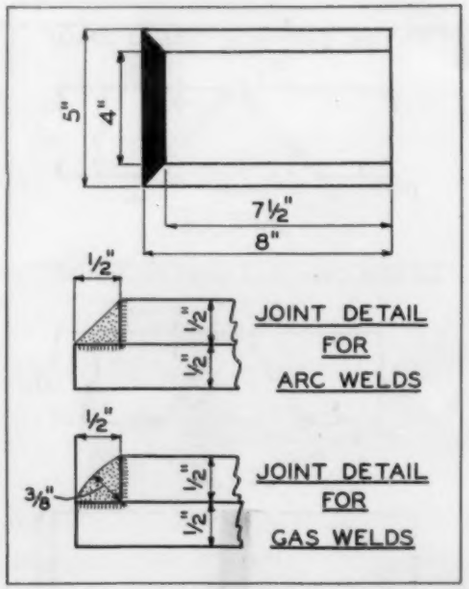
Both welder and inspector then examined the fractures for penetration, reinforcement, and appearance of weld metal.

2-4-2 MANDATORY TESTS (ARC AND GAS)

These tests were required of all welders. Where the welder's experience justified the inspector in omitting the optional tests, the Committee still deemed it desirable to examine the quality of the welder's work before permitting him to weld the tension specimens.

2-4-2-1 Wedge Test—A rapid, inexpensive, and withal, excellent test was the so-called wedge test. It required the welding of two or more specimens similar to Fig. 5. After the weld was completed and had cooled, the specimen was torn apart by driving a suitable wedge between the bars at the unwelded end, thus prying them apart until the weld ruptured.

Inspection of the fractured metal then showed the quality of deposited metal, the fusion of deposited metal with the base metal, and the degree of penetration into the right angle corner of the fillet (root of weld).



SPECIFICATIONS

Clamp bars securely.

Specimens to be welded flat.

Penetration required well into root.

FOR ARC WELDERS

Reinforcement — None, surface straight.

No. of layers—2.

Amperes—Approx 200.

Size of Electrode—3/16".

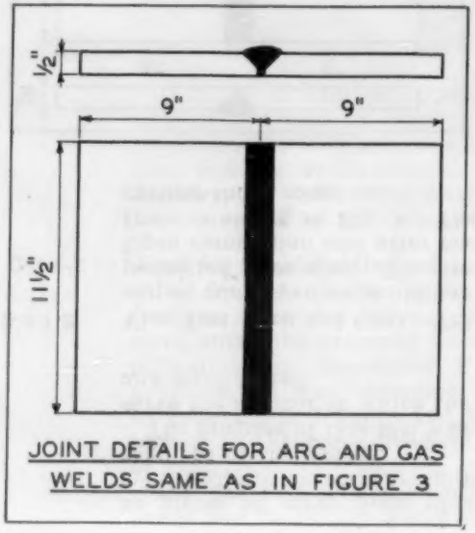
FOR GAS WELDERS

Reinforcement—Surface rounded as shown.

Speed—any.

FIG. 5—SPECIMEN FOR WEDGE TEST

2-4-2-2 Tension Test—This test is one that provided quantitative results. It required the welding of five (5) plates similar to Fig. 6. Three of these plates were welded in a flat posi-



SPECIFICATIONS

Single Vee Butt Joint welded one side only.

Penetration—100%.

Reinforcement — 20% of plate thickness.

FOR ARC WELDERS

No. of weld layers—2.

Amperes—Approx.:
Flat 200.
Vertical 175.

Size of Electrode 3/16".

Note: Before welding the plates shall be tack welded at the ends of the joint.

FOR GAS WELDERS

Minimum speed per hour: 2 ft. Flat, 1½ ft. Vertical.

Note: Plates shall be firmly clamped to a suitable support and must be properly spaced to allow for contraction of joint during welding.

FIG. 6—SPECIMEN FOR TENSION TEST

base metal, and the degree of penetration into the right angle corner of the fillet (root of weld).

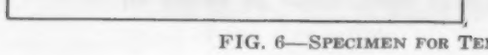


FIG. 6—SPECIMEN FOR TENSION TEST

tion, that is, the specimens were placed flat on a welding table or other suitable support, and two of the plates were welded in a vertical position, that is, the longitudinal axis of the joint was upright or vertical during welding.

A butt-welded form of specimen was selected for the reason that it had been found satisfactory in other classes of work. During the progress of this investigation it became evident that a fillet welded specimen would have been better suited to structural work. (Sections 7-12 and 8-1-2.)

The grade of material for these specimens was identical with that used in the program specimens, and its physical and chemical properties were similar to those given in Appendix 10-1.

From each of the plates, four (4) standard American Welding Society* Test Coupons were cut as shown in Fig. 7. Before the plate was cut into coupons, a mark identifying the particular plate was stamped on each of the four coupons. After marking, the plain coupons were removed from the plate at the shop by sawing or by cutting with a gas torch. Each coupon was then machined to dimension, and all reinforcement of the weld above the base metal was removed by machining or grinding, so that the thickness of the coupon at the weld did not exceed that of the base metal.

The 20 coupons to be tested in tension were then shipped to the laboratory designated by the Committee.

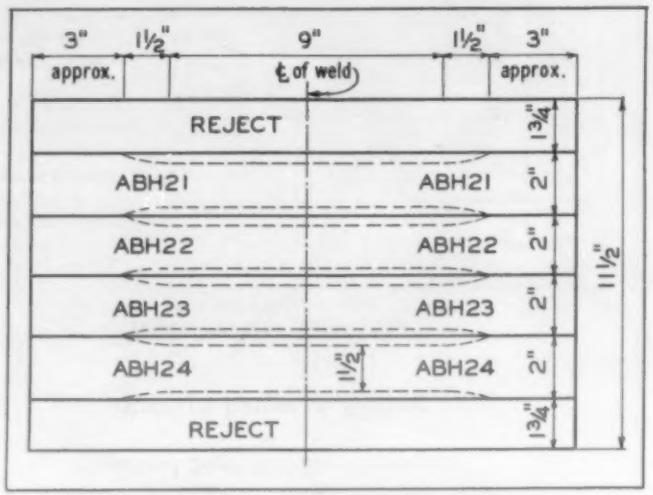


FIG. 7—COUPONS FOR TENSION TEST

*See Bulletin No. 1 American Bureau of Welding; also A.S.T.M. Standards A7-24, A8-24, A9-24, etc., and A.S.T.M. Tentative Standard E8-25T. The essential dimensions are width of reduced section 1½ in., length 9 in., ends 2 in. wide and about 3 in. long. Fillet radius between 1 and 3 inches.

REQUIREMENTS

In order to qualify, the following strengths per sq. inch of weld throat were required:

Arc—An average of 45 kips, with a minimum for any individual coupon of 40 kips.

Gas—An average of 52 kips, with a minimum for any individual coupon of 50 kips.

At the time these requirements were agreed upon, the usual values for gas welding were higher than those for arc welding. It was the hope of the Committee that the tests might furnish a single basis that would be suitable for either process. (Section 8-1.)

2-4-3 DATA RECORDED BY INSPECTORS

To make the recording of the required data as simple as possible, the Committee provided inspectors with Standard Forms 100, 101, and 102. Form 100 was a log of the welder's experience. Forms 101 and 102 were provided to record the information desired by the Committee pertaining to the welding of the qualification specimens.

Form 101 for arc welders is shown in Fig. 8. Form 102 was furnished for gas welders, but since it differed only in process details, is not shown here.

2-4-4 DATA RECORDED BY LABORATORIES

Each of the 20 coupons was tested for tensile strength and reported by the laboratory on Form 105. While no yield point was specified, it was reported by some of the laboratories. In addition, the appearance of the fracture was recorded to explain variations in strength.

2-4-5 PROGRAM SPECIMENS RELEASED

In general, no welding was permitted on program specimens prior to receipt of the laboratory report on qualification tests. If specified strength requirements were met, the welder was approved and the shop advised to proceed with the welding of the program specimens.

In those cases where the welder failed to comply with the qualification requirements, arrangements were made for a repetition of the tests at a later date. If for any reason such test could not be arranged, no program specimens were authorized. Exceptions to this rule are explained in Section 3-1.

2-4-6 DATA SUMMARIZED BY COMMITTEE

The data recorded by inspectors and laboratories have been summarized and tabulated in Appendices 10-2 and 10-3.

Appendix 10-2 contains the log of the welder's experience and the results of his butt weld qualification tests. Appendix 10-3 tabulates the welding wires used.

Structural Steel Welding Committee
of
American Bureau of Welding

Form 101
Inspectors' Form for Qualifying Tests
Metal Arc Welding Process

FABRICATING PLANT	B			
WELDERS IDENTIFICATION	B			
TYPE OF QUALIFICATION TEST		a	b	c*
POSITION OF SPECIMEN DURING WELDING	Horizontal	X	X	X
	Vertical		X	X
RATE OF WELDING IN FEET PER HOUR	Horizontal	2.5	2.5	2.5
	Vertical	2.0	2.0	2.0
DATES OF TEST		2-5-29	2-7-29	2-7-29
NUMBER OF COUPONS TAKEN		3	3	5
WELDING WIRE	Trade Name RECORDED		Same	Same
	Diameter in Inches	3/16	"	"
ARC WELDING MACHINE check DC ✓ check AC	Make RECORDED		"	"
	Type	63-S/C	"	"
	Capacity	300 A	"	"
ARC CHARACTERISTICS check DC ✓ check AC	Average Amperes	200 H 175 V	"	"
	Average Volts	20	"	"
REMARKS	On BHV 4 plate welder had trouble with blowing through of weld.			

NOTE: Under REMARKS, shall be noted any irregularities that might occur or develop during the tests, such as defective base metal, improper welding arc, fluctuating current, lapping of plates due to improper spacing, non-continuity of welding, etc.

*NOTE: PLATE AND COUPON IDENTIFICATION FOR "c" SPECIMENS. Each coupon in each plate shall be marked on both ends, as follows:

First letter is to be the Shop Designation.
Second letter is to be the Welders Designation. These letters, assigned by the Inspector, shall be A, B, C, etc., depending upon the number of welders assigned by the shop to the work.

Third letter is to show by H or V whether the specimen has been welded in a horizontal (flat) or vertical position.

The 1st number at the end corresponds to the number of the test plate, whether it be the 1st, 2nd or 3rd plate, etc., welded, and the last number is to identify the position of the coupons taken from the plate, as No. 1, No. 2, No. 3, No. 4. See Fig. 5, Sec. B.

Therefore, with Welder B from Shop "A" welding the second specimen of the "c" test horizontally, the coupons cut therefrom would bear the identification ABH21 to ABH24.

FIG. 8—FORM 101, TYPICAL INSPECTOR'S REPORT

2-5 FABRICATION OF PROGRAM SPECIMENS

2-5-1 GRADE OF STEEL

The grade of steel used for all program specimens was Open Hearth Structural Steel for Buildings conforming to A.S.T.M. Specifications A-9. The heat number reported by the mill supplying the material is given for each specimen in Appendix 10-4. The physical and chemical properties of the steel in each specimen may be ascertained by referring to Appendix 10-1 in which these properties are given for each heat.

The tests made by the U. S. Bureau of Standards check the ultimate strengths reported by the mills with reasonable closeness. The yield points vary to a greater extent, and this is in line with usual experience, namely, that the personal equation of the observer is an important factor when the drop of the beam method is employed.

Two shops, XA and DR, as mentioned in Section 2-3-1, furnished their own material, reported to be of usual structural steel grade.

2-5-2 PROCESSES

No restrictions were imposed by the Committee as to which fusion processes should be used. Four welders employed the Oxy-acetylene Gas process, welding backhand; one welder the Alternating Current Arc process; all other welders used the Direct Current Arc process.

In this report the specimens welded by the oxy-acetylene process are referred to as gas specimens; and those welded by the alternating or the direct current arc process are referred to as arc specimens.

2-5-3 PREPARATION FOR WELDING

In order to keep the variables in these tests to a minimum, it was required that all joints be prepared by machine tools usually found in fabricating shops (power shear, saw, miller, shaper, or planer). Allowable tolerances for squareness of joint faces to be welded were within the limits of good shop practice; for beveled joint faces to be welded, within 5 degrees either way; and for root spacing of butt joints, within 1/32 in. of the specified dimension. To avoid eccentricity of load during the test, specimens were carefully aligned before welding, and were kept in position by clamping rigidly or by tack welding.*

The welding surfaces of all bars were carefully cleaned of foreign matter and rust with a wire brush immediately be-

*A tack is an intermittent weld used for assembly purposes only. For these specimens tacks were specified about ½ in. in diameter.

FIG. 8—FORM 101, TYPICAL INSPECTOR'S REPORT

*A tack is an intermittent weld used for assembly purposes only. For these specimens tacks were specified about ½ in. in diameter.

fore welding. In order to better observe strain lines during test, care was taken not to remove mill scale.

Where multi-layer welding was specified, the surface of an arc weld was carefully cleaned of adhering scale with a wire brush or by chipping before adding more layers of weld metal.

2-5-4 POSITION OF SPECIMEN DURING WELDING

All specimens were welded with the longitudinal axis horizontal and with the faces of the c bars lying flat on the welding table or support* with the exception of Series 6800 and 6900, which were welded with the faces of the c bars in a vertical position.

Where welding was required on both sides of a specimen, it was turned over after the welding on one side had been completed.

Specimens were not permitted to be inclined to facilitate welding, but were required to be in the specified position at all times during the welding operation.

2-5-5 FILLER METAL (WELDING RODS AND ELECTRODES)

Gas welding rods were required to be of a grade that would develop a minimum of 56 kips per sq. inch in tension in a butt weld joining two mild-steel plates.

Arc welding electrodes were required to be bare wire conforming to the American Welding Society specifications designated as Class E-1-A or E-1-B.

A list of welding rods and electrodes used in welding the program specimens is given in Appendix 10-3.

2-5-6 PREPARATORY TACKING

All specimens were clamped or tacked before welding. In the larger specimens, particularly, tacking was employed. A suitable location of tacks was indicated, as reproduced on the design data sheets of Appendix 10-4. As tacks were encountered during the final welding (in the gas process only) they were required to be thoroughly rewelded.

2-5-7 WELDING ARC

The current used, as reported by the shops, was at all times within 5 per cent plus or minus of that specified for each specimen group. The potential across the arc was approximately 20 volts.

*See sketches in Appendix 10-4.

2-5-8 WELDING FLAME

A neutral flame was recommended possessing either a relatively short, round end cone produced by throttling gas pressures when using an oversize tip; or a relatively long, round end cone produced by the correct tip size with correct gas pressures.

2-5-9 GAGING WELDS

As the purpose of this investigation was to test definite sizes of welds, it was necessary that welds be kept within certain specified tolerances. The more closely the weld conformed to the average the more nearly did it serve its purpose in the program.

TABLE II
WELD PROFILES

FILLET WELDS

Designed Size Inches	LEG			THROAT		
	Minimum	Normal	Maximum	Minimum	Normal	Maximum
¼	¼	5/16	3/8	0.177	0.221	0.265
3/8	3/8	7/16	½	0.265	0.309	0.354
½	½	9/16	5/8	0.354	0.398	0.442
5/8	5/8	11/16	¾	0.442	0.486	0.530
¾	¾	13/16	7/8	0.530	0.574	0.619

BUTT WELDS

Plate Thickness Inches	Reinforcement Single Vee			Reinforcement Double Vee Each Side			Minimum Width of Reinf. Gas Welds
	Minimum	Normal	Maximum	Minimum	Normal	Maximum	
¼	0.0625	1/16	0.125	.....	..	.....	5/8
3/8	0.0625	1/16	0.1563	.....	..	.....	15/16
½	0.0938	1/8	0.1875	0.050	1/16	0.150	1¼–5/8
5/8	.....	..	.....	0.0625	1/16	0.1605	15/16
¾	.....	..	.....	0.075	1/16	0.175	15/16
7/8	.....	..	.....	0.0875	1/16	0.1875	1 5/16
1	.....	..	.....	0.100	1/16	0.200	1¼

A supply of 100 sets of the gages shown in Figs. 9 and 10 were made up for the Committee. Each inspector, shop, and laboratory was supplied with a set to insure the uniformity desired.

The terms, Minimum, Normal, and Maximum, used in reporting the profiles of butt and fillet welds are based on Table II.

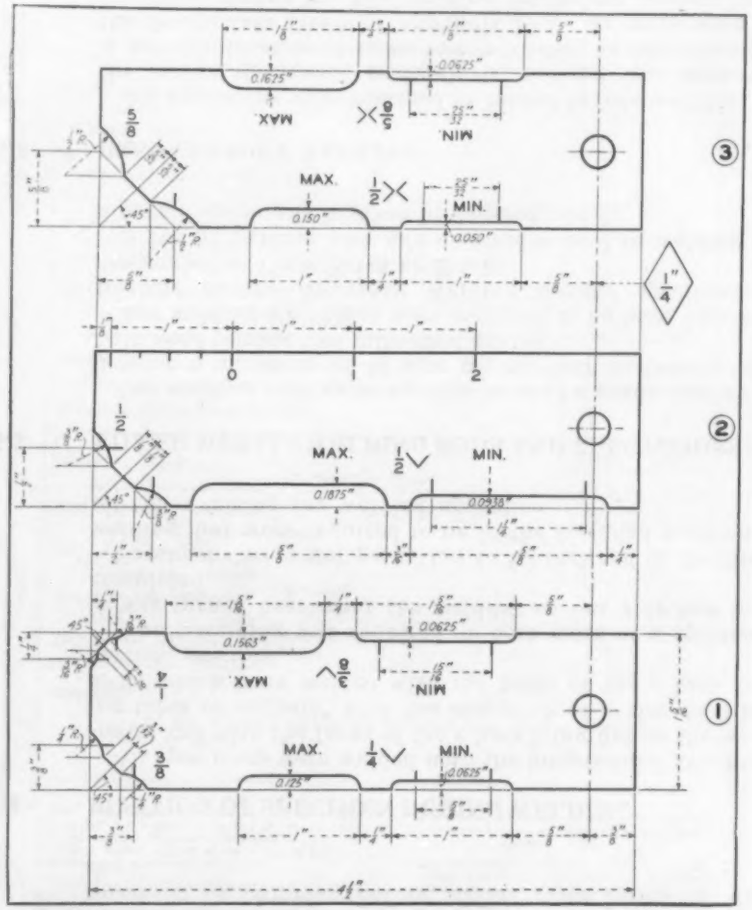


FIG. 9—WELD GAGES

2-5-10 HEAT TREATMENT (NONE)

Specimens were not preheated either before or during welding, and were not subjected to heat treatment of any kind after welding was completed, but were allowed to cool normally in air to room temperature.

2-5-11 IDENTIFICATION MARKS

A special system of numerical designation was adopted to readily identify specimens. The first two digits in a number are considered the series number proper. The third digit denotes plate thickness in eighths of an inch (c bar in Series 6200, 6300, 6400, 6500, 6800, 6900, b bar in all other cases). The fourth digit represents the weld dimension, also in eighths of an inch; the throat for butt welds, the leg for fillet welds. The capital letters designate the shop, and the number following identifies one of a number of identical specimens welded by the same shop. Thus, 2343 LZ2 represents the second specimen welded by Shop LZ of Series 2300, having b bars ½ in. thick (four-eighths) and a ⅜ in. fillet weld (three-eighths).

2-5-12 DATA RECORDED DURING FABRICATION

Forms were furnished the shops upon which to record such data as the Committee desired. Fig. 11 illustrates the manner in which this information was transmitted on Form 104 for gas welding. A similar Form 103 was furnished to

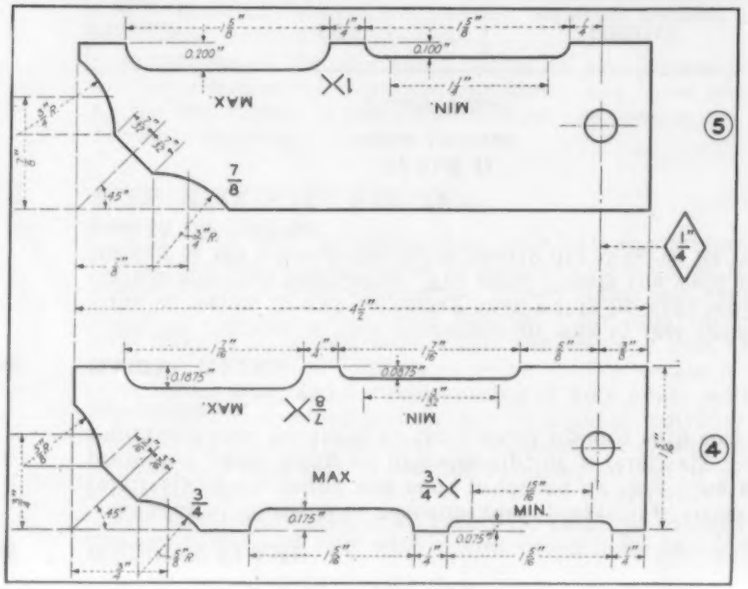


FIG. 10—WELD GAGES

FIG. 10—WELD GAGES

record the fabrication data of specimens welded by the arc process.

Structural Steel Welding Committee of American Bureau of Welding

FORM 104—DATA SHEET FOR PROGRAM TEST SPECIMENS

FOR OXY-ACETYLENE WELDED TEST SPECIMENS ONLY (TO BE FILLED OUT BY WELDING INSPECTOR)

1	Specimens Mark	3186
2	Number of Specimens	2
3	Welders Identification	A

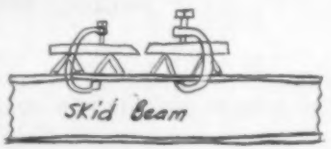
WELDING TORCH DATA		
4	Make	RECORDED
5	Type	W1 - 2
6	Nominal Tip Size	#10

WIRE DATA		
7	Trade name and grade of welding wire. (Inspector shall send 3 samples of wire approx. 12" long to Sec'y of Committee)	RECORDED
8	Diameter of welding wire	3/16
9	Number of inches of wire consumed	D1 - 118" D2 - 122"

SPECIMEN DATA				
10	Marking on bar metal		On "b" bar	On "c" bar D1 - D2
11	Cleanliness of bars before welding		Good	
12	Weight of specimen before welding in pounds		29#	
13	Weight of specimen after welding		29#	
14	Inspection of the preparation of bars for welding	(a) Total angle of bevel	90 degrees	
		(b) Shoulder dimension	1/16"	
		(c) Squareness of faces		
15	Spacing of joint before welding	At start end 1/16"		
		At finish end 1/4"		

WELDING DATA				
16	Approximate dimension of tacks if used			
17	Gas pressures during welding	Av. oxy. press.	70 lbs.	
		Av. acet. press.	7 lbs.	
18	Characteristics of welding flame. Specify by number. See Section "D"	#2		
19	Method of welding see Section "D"	Forehand		
		Backhand	X	
20	Welding sequence by numbers			
21	Actual time of welding specimen in minutes	D1 - 38 min.		
		D2 - 38 min.		
22	General quality of bar metal	Good		
23	Reinforcement check if within gauge tolerance. See Sect. "C"	Min.		

24 If specimen is clamped for welding make sketch showing method of clamping



25 Remarks

All Butt Welded Specimens clamped like this.

26	To which laboratory was specimen sent after welding		
27	Date sent by laboratory		
28	Date rec'd by laboratory		

Name of shop D — Inspector SIGNED

Witness — Date 9/25/29

FIG. 11—FORM 104, TYPICAL SHOP REPORT

2-5-13 SPECIMENS ASSIGNED AND WELDED

Assignment Group	Specimens Assigned: Per Division	Specimens Assigned: Total 3 Divisions	Specimens Welded and Tested	Percent Assigned Specimens Welded and Tested
1	141	423	390	92.2
2	64	192	128	66.7
3	49	147	147	100.0
4	45	135	135	100.0
5	42	126	125	99.3
6	39	117	58	49.6
7	38	114	95	83.3
8	33	99	49	49.5
9	35	105	80	76.2
10	26	78	78	100.0
11	26	78	47	60.3
12	21	63	63	100.0
Total.....	559	1,677	1,395	83.2

While only 83 per cent of the contemplated program was completed, test reports were received on all specimen groups. Inspection of the graphs and tables shows that where some of the assigned specimens were not prepared, those specimens which were tested furnished sufficient information from which to draw reliable conclusions.

2-5-14 PACKING OF SPECIMENS FOR SHIPMENT

After welding and marking, the specimens were carefully crated for shipment to the laboratory designated by the Committee. It was important that the specimens be delivered to the laboratory in the same condition as when the welding was completed and to this end special precautions were taken to protect them against damage in transit. The exact manner in which shipments were made was left to each shop.

2-6 TESTING OF PROGRAM SPECIMENS

2-6-1 SPECIFICATIONS

Since the testing of specimens was to be distributed among many laboratories, Section F of the Specifications was prepared to inform the laboratories of what was desired and to outline the procedure for testing. Form 106, Fig. 12, was printed and furnished the laboratories upon which to record test data.

2-6-2 ADJUSTMENT OF SPECIMENS

All testing machines were properly calibrated and care was taken to insure parallelism of the inner faces of the grips. Each specimen was then placed in the machine and gripped axially, and so located that the clearance was 4 in. from the inner end of each grip to the center of the butt-weld, or to the end of the b bars in the case of other welds.

2-6-3 SPEED OF TESTING

Up to the yield point the speed was not to exceed ⅜ inch per minute. Above the yield point that speed was increased if desired.

When necessary, the machine was stopped at intervals in order to permit closer observation of, and the recording of strain lines on the specimen.

2-6-4 DATA RECORDED BY LABORATORIES

Before testing, each laboratory checked the identification marks and the dimensions of each specimen against those specified by the Committee. The weld sizes were reported as "Minimum, Normal, or Maximum," in accordance with the classification given in Table IV. The gross lengths, including craters in arc welds, were reported, and these are the dimensions recorded under the caption "Weld Length" in the tables of Appendix 10-4. The rules for measurement had been covered by the supplementary instructions referred to in Section 2-3-4-2.

In addition to the loads corresponding to yield point and ultimate strength, there were also recorded loads at which any of the welds showed unusual behavior. All specimens were coated with a thin cement whitewash to facilitate observation of surface strain lines. The development of these lines was recorded by means of sketches and photographs.

The location and appearance of all fractures were similarly described and reports made as to degree of fusion and penetration.

A typical report is shown in Fig. 12.

Although the laboratories computed and reported unit weld strength, the Committee re-calculated these values for all specimens in accordance with the rules given in Section 5-1.

(Report to be continued in next issue)

Structural Steel Welding Committee
of
American Bureau of Welding

Form 106
Laboratory Report of Tests of
Program Test Specimens

Laboratory REPORTED

Observers SIGNED Date 1/19/31 ... 2/1/31

Specimen Series No. 2155 - Spec. No. 1 ... Total inches of weld 4"

Welding Identification: Operator ... Shop "X"

Welding Process: Electric REPORTED Gas ...

Yield Point total 54,000 lb. 13,500 lb. per linear in.

13,500/.530 = 25,450 lb. per sq. in.

Ultimate Load total 73,210 lb. 18,300 lb. per linear in.

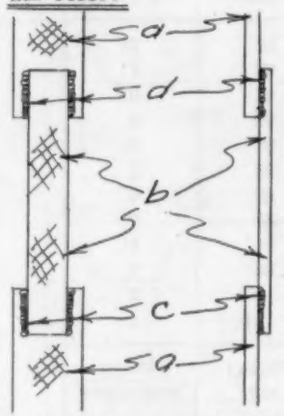
18,300/.530 = 34,600 lb. per sq. in.

Load at which first weld failed ... lb.

... lb. per linear in.

... lb. per sq. in.

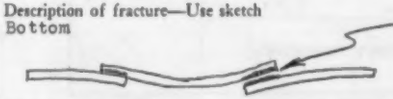
Max fillet



Note Load lb. at which strain lines occur and location. Use sketch.

a	40,460	scaling
b	51,960	"
c	54,320	"
d	56,470	"
e		
f		

Description of fracture—Use sketch
Bottom



Use additional sheets

FIG. 12—FORM 106, TYPICAL LABORATORY REPORT

Welding of Piping in New York Hospital—Cornell Medical Clinic

By C. J. THALE

✦A paper presented at Fall Meeting, A. W. S., September, 1931, by C. J. Thale of Almirall & Company.

IT is not our intention to endeavor to set forth the value of welding, nor to compare the costs of welding with the old screwed or flanged pipe and fitting installation, as the cost of welding depends almost entirely on the labor cost which varies greatly over the country. Rather we propose to review briefly from the construction standpoint the procedure of a large welding installation as experienced in the heating, refrigerating and ventilating contract for the New York Hospital and Cornell Medical College Association Group located in New York City.

The members of the American Welding Society who visited the Medical Center in the spring of 1931 will recall that it consists of a group of nine buildings covering three large city blocks. The piping work at the time of that visit was only about 25 per cent complete. At present the major part of the work is finished.

When we were awarded this contract in the summer of 1930, the problem that gave us greatest concern was one of method of procedure to give quickest results. We had a close to $2,000,000 contract to have completely installed in a little over twelve months.

The general construction of the buildings was advancing rapidly. The main hospital was up to the twelfth floor, the women's building to the sixth and the college buildings were being topped out. The general contractor was calling for piping to be installed.

To obtain a sufficient number of good welders for this job, presented quite a problem. The Empire State Building, a large welding operation, was in full course of construction. We had a large welding job at the new Eighth Avenue Subway 207th Street Repair Shops, and there were other jobs requiring experienced pipe welders in various parts of the Metropolitan District. Successful welding depends largely upon the human element, and it was necessary to exercise extreme caution in the selection of the men to do the job. To make sure of the experience and knowledge of welding by those who applied for jobs, we set up a testing room on the job and before a man was fully accepted he had to pass several tests made under the observation and scrutiny of an experienced welder.

Two methods of operation were open to us:

We could ship pipe to our shops in Glendale, L. I., where we continuously maintain a force of welders, and there weld in all nozzles, flanges, etc., and generally prepare the pipe to minimize the amount of field welding.

This method of procedure had the usual difficulties of a screwed or flanged installation. The pipe had to be handled from the cars to storage, to the shop and from the shop to truck. Trucking through the congested streets and the difficult handling of long awkward sections into final location at the buildings.

Our other alternative was to build up a sufficient force of welders and do all welding on the job.

After a careful analysis, in spite of the shortage of welders, this latter method seemed to give greatest promise, both from the standpoint of speed and cost.

All pipe from 2½ in. to 20 in. was ordered from the mill with beveled ends prepared for welding.

The pipe was delivered in carload lots by lighter to within two blocks of the job. It was delivered in building units so that the handling and distribution were reduced to a minimum.

In distributing piping the random lengths were laid out on the floors roughly in position, and tube turns, forged steel butt welding flanges, and other fittings were welded on the pipe in approximately the position shown on the drawings.

While the piping was being distributed and fitted, the permanent hangers were being installed. As rapidly as hangers were erected these previously prepared lengths were laid up on them and permanently welded together.

In installing the mains no consideration had to be given to the outlets for risers, connections, etc., as many weeks afterward these nozzles could be welded in to suit the exact locations of the runouts to risers and other connections. With a screwed or flanged job this would not be possible, as the exact location of all outlets would have to be previously determined and considerable shop work executed before installation could begin.

The anxiety due to the liability of leaks at flanges was practically non-existent, as the only flanges in this installation are at valves and final connections to apparatus.

The nozzle outlets from the mains are extra heavy screwed couplings for all pipe up to and including 2 in. Over 2 in. we used pieces of pipe formed to the main and welded in the usual way.

A very distinct convenience in doing welding on the job indicated itself as the work progressed. This was in making the numerous but inevitable alterations due to job conditions and architectural changes that developed as the work went on. It was only necessary to weld in an additional outlet here and there to suit conditions, or even where whole runs of mains had to be re-located it only meant to part the mains with the burning torch, relocate and weld together again, leaving no scrap material or odd sized flanged tees to be sent back to the shop.

There was also a distinct advantage in being able to do iron work on the job in connection with supports, hangers and anchors and tools.

All piping in this operation was tested to 350 lb. hydrostatic pressure immediately after the various sections had been welded together.

The various types of piping welded are:

High pressure steam piping for 200 lb. steam working pressure.

Medium pressure steam, 30 lb. to 200 lb.

Low pressure steam, 5 lb.

Hot water heating piping static pressure 30 story building.

Brine piping.

There were approximately 40,000 diameter inches of pipe welding done on the job, and difficulty from leaks

was surprisingly small. A careful check-up of inches of welding per man per day was kept and every weld made was stenciled by the man who made it, thereby enabling us to trace a faulty weld to the man responsible for it. From a construction standpoint it was a most satisfactory installation in every way, and permitted of a very economical and attractive covering job.

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